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UNITED STATES BENEFITS OF IMPROVED WORLDWIDE WHEAT CROP INFORMATION FROM A LANDSAT SYSTEM

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UNITED STATES BENEFITS OF IMPROVED WORLDWIDE WHEAT CROP INFORMATION FROM A LANDSAT SYSTEM

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NOTE OF TRANSMITTAL

This report is prepared for the Office of Applications, National Aeronautics and Space Administration under Statement of Work on Contract NASW-2558 which represents an evaluation of the improvement in worldwide wheat crop information promised by a LANDSAT-type Earth Resources Survey (ERS) System.

The results reported herein are based on the best public data available on world wheat crop information. The economic approach used for this study represents significant innovations in the valuation of improved information on agricultural crops. In addition to this report, a separate volume providing an overview of this study is transmitted. In the Overview, the issues, assumptions and results of the study are summarized. To our knowledge, this is the first empirical assessment of the economic value of a LANDSAT system in providing information on the worldwide wheat crop.

Other than the study director, the principal participants in this study effort were Francis Sand, Andrew Seidel, Dennis Warner, Neil Sheflin, Ran Bhattacharyya and John Andrews, each of whom made important contributions to this study.

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Study Director

ABSTRACT

The Earth Resources Survey (ERS) and the LANDSAT Program of NASA in particular, face some important decisions over the next 12 to 18 months that will affect the future of remote sensing by satellite in civilian applications for decades to come. To provide an economic basis for the discussion of these issues, ECON, Inc. completed an overview evaluation of a LANDSAT-type Earth Resources Survey system in 1974*. Potentially large benefits to be obtained in agriculture from a continuity of LANDSAT data services when applied to the United States were identified and measured.

This report is an extension in breadth and depth of these ECON agricultural case study efforts. The value of worldwide information improvements on wheat crops, promised by LANDSAT, is measured in the context of world wheat markets. These benefits are based on current LANDSAT technical goals and assume that information is made available to all -- United States and other countries -- at the same time.

The benefits to the United States of such public LANDSAT information on wheat crops are, on the average, 174 million dollars a year. About 287 million dollars accrue

*ECON, Inc., The Economic Value of Remote Sensing of Earth Resources from Space: An ERTS Overview and the Value of Continuity of Service, 10 Volumes, Princeton, New Jersey, December 1974.

directly to United States consumers in the form of lower average wheat prices; $280 million are production efficiency gains in providing for domestic and foreign demand. These benefits are those of a LANDSAT system with possibly as many as three operating spacecraft. The benefits from improved wheat crop information compare favorably with the annual system's cost of about $62 million.

A detailed empirical sample demonstration of the effect of improved information is given; the history of wheat commodity prices for 1971-72 is reconstructed and the price changes from improved vs. historical information are compared.

These results reaffirm the conclusions reached by ECON in its December, 1974 report in the most important area: LANDSAT promises substantial benefits from improved information in agriculture if present technical goals and expectations are met. The improved crop forecasting from a LANDSAT system assumed in this study are: wheat crop estimates of 90 percent accuracy for each major wheat producing region, at a 90 percent confidence level through the wheat harvest period. This translates roughly into a 1.8 percent error in December wheat crop production estimates for the United States and 5.0 percent for the rest of the world.

The technical performance and capabilities of a LANDSAT system are still being developed by NASA; our estimate

on technical capabilities of a LANDSAT system are based on a considered interpretation and extension of LANDSAT investigations to date, and were given to us by NASA.

In conclusion, accurate, objective worldwide wheat crop information using space systems may have a very stabilizing influence on world commodity markets, in part making possible the establishment of long-term, stable trade relationships.

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1. THE VALUE OF CROP FORECASTING: METHODS AND RESULTS

1.1 Introduction

In this age of overabundant demands for agricultural supplies, official organizations and technological systems have been called on to perform as sorcerers and talesmen to whom the economic community can turn for information about the future. To many, these agencies and systems only prove the folly of forecasting the future and trying to defy fate. At best, official organizations and their technological systems may only grant what society can reasonably ask for, a "state-of-the-art" estimate, and not what society often demands or thinks it has asked for, the unambiguous truth.

It is unfortunate, but true, that official wizards of economic phenomena only can provide a clouded picture of future events. Nevertheless, it would be ill-advised to throw these "services" into the fire as long as their forecasts offer information that result in <u>net</u> benefits to society. This criterion, of course, presupposes that information and information systems in general can be evaluated.

The objective of this study is an attempt to measure the value of improved crop forecasting information. In this sense, this study -- and related work by ECON -- is breaking new ground in economics. The first step in this task must be to set forth the analytical foundations from which to make that assessment. We discuss here the role of information in the

market process. We then discuss the measurement of the most important attributes of crop forecasts and the statistical methods for analyzing them. The meaning of the terms "forecast" and "estimate" are defined as used in this study. Finally, we set forth the analytical foundations from which the economic losses owing to misinformation and the economic gains from information improvement will be measured.

1.2 Information and the Market Process

We should fix in our minds precisely what is implied in the statement that a resource has been misallocated in a market system. Let us consider a unit of a particular resource that has been employed, together with quantities of other productive factors, in the production of a particular product. The use of this resource to this end has deprived others of the productive contributions it might have rendered in some alternative employment. On the other hand, consumers under the existing arrangement can enjoy the productive contribution that the unit of resource is making in its present employment. In a market system, there is a market value placed upon each of the various foregone productive contributions that might have been rendered elsewhere by the unit of resource and there also is a market value placed upon the productive contribution that the unit of resource actually does render. In a "free market" economy, "usefulness" is measured by market value or prices.

Following Kirzner [69], a natural meaning of the term "misallocated resource" in the above context would be the use of a resource in an endeavor that does not command the price of one or more foregone alternative uses. This is not to say that a resource is "misallocated" if it is in the "wrong" place in terms of actual market prices and with respect to a state of the economy as it is. We speak of waste or loss here in a normative context, i.e., what should be, because under the current conditions of the market, a resource is being used in an employment that a market declares to be less important than an alternative available employment. Our task now is to determine what gives cause to waste.

Although many special theories and particular examples can be given of how waste can appear in an economy, as Kirzner [69] and Harberger [39] point out, there is in fact <u>only one</u> way a resource may be misallocated: as a direct result of the imperfection of the knowledge of market participants. If knowledge of all relevant data were possessed by all participants, no perverse discrepancy could exist between the market value of the productive contribution of a factor in its actual employment and the value of its potential contribution elsewhere. With perfect knowledge, the price of the unit of the factor would be the same in all areas of the market; differences in the technological efficiency of the factor in different uses and differences in the desirability to consumers of the different

products would be fully reflected in the prices and output volumes of the various products. No room would be left for a perverse difference between the market values of actual and potential productive contributions.

Now, if we consider a situation where all the available information initially is inaccurate and/or widely scattered in the form of scraps of knowledge possessed by individual participants, then resources would be misallocated owing to this imperfect knowledge. A resource may be employed in a less important manner because the entrepreneur is unaware of the more important possible employments and does not know of the availability of this resource. In the first case, the enterpreneur using the resource in the less important employment may be unaware of the greater technological productivity of the resource in other branches of production and/or the higher prices obtainable in the market for the other products. In the second case, the enterpreneurs who are unaware of the more important productive contribution that such a resource can make elsewhere may mistakenly believe that the price of the resource is too high to make its use worthwhile in these more important employments.

In general then, the misallocation of a resource can be equated with widespread (if uneven) ignorance of the gaps and errors in pertinent information. Some market participants may know all about one piece of information (for example, the availability of the resource), but have incorrect information about other pieces of information, such as its

highest price. Because no one simultaneously knows both these pieces of information, no one is aware of any true (perfect knowledge) possibility of improving the existing allocation of resources. An appraisal of the efficiency of the market process, therefore, involves an appraisal of the way the market process disseminates the information necessary for the discovery of superior opportunities for the allocation of resources. This is valid for both a "static" economy where tastes, productivity and resource availability are constant and a dynamic economy where resource availability, productivity, and consumer tastes are free to change. The efficiency of the market process in both cases is a question of its ability to transmit to the relevant decision-makers those pieces of information necessary for the "correct" allocation of resources in terms of the market conditions.

In effect then, inaccurate information leads to input market distortions: resources (commodities, capital, labor) are allocated (used) for tasks that under better (perfect) information would not have been undertaken. The larger this ignorance, the larger these distortions. In a way ignorance can be equated to imposing a "tax" on input factors, thereby leading to economic costs throughout the economic system, with the consumer of final goods ultimately paying the imposed cost of inaccurate information.

A reduction in ignorance, i.e., improved information, conversely can be equated with lifting this "tax" on input

factors. This latter topic and the assessment of the economic costs of such "taxes", has been widely dealt with, most recently -- and most extensively -- by D. Wisecarver [127]. (See References.)

With regard to agriculture in particular, estimates of crop acreage and yields, leading to forecasts of total production levels, are essential for efficient planning in all phases and segments of agricultural production, processing and distribution. Accurate forecasts permit precise planning for more efficient transportation and processing of commodities and can help identify potential shortages while there still is time to "hedge" against them. Reliable final yield and acreage estimates provide the information necessary to coordinate the supplies and demands for farm machinery and storage services.

Inasmuch as commodity prices fluctuate by large amounts within any one crop year, or even one month, one can interpret this directly as the inverse to the total supply the market believes -- rightly or wrongly -- to be available this month, next month and n months hence. And since commodity prices fluctuate quite violently (see Figure 1.1 for wheat), these expectations or beliefs of the market seem to fluctuate quite widely -- if not randomly.

Since commodity markets -- with a well organized futures market -- are as close as the economists' model of pure competition -- with the ensuing possibility to empirically

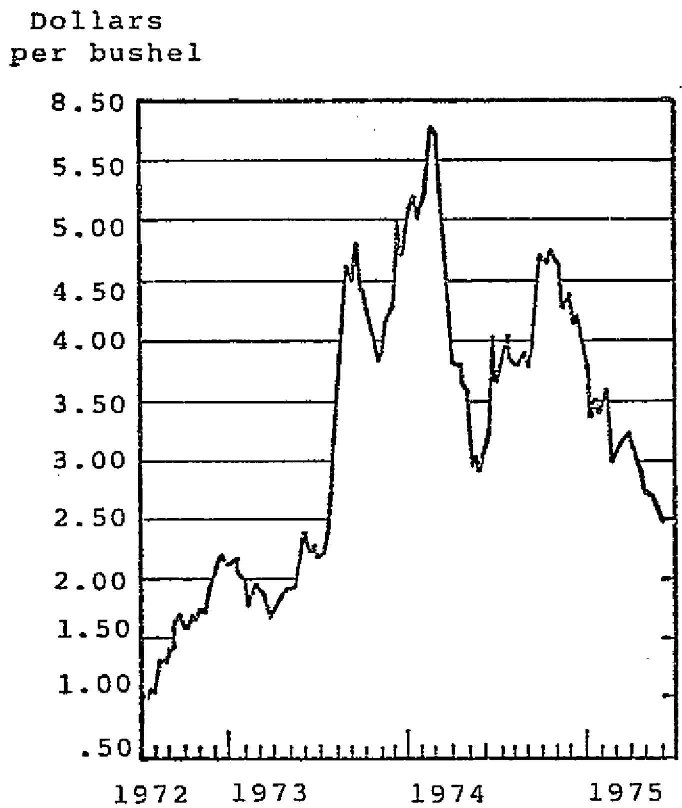

Figure 1.1 Wheat Price Movement,
1972-1975

apply and test some of the theoretical insights of current economic theory -- they also are an ideal place to model and measure the effect and value of information and improved information [20].

It is the working hypothesis of this study -- investigated and measured in subsequent chapters -- that improved information on agriculture crops (wheat) will enter over futures market prices to the spot market prices with a general smoothing effect of commodity prices -- spot and futures.

To state our hypothesis in graphical form, we plotted in Figure 1.2 the winter wheat spot price, by month, for 1972, with information and sources of information as they were. The major single event in that year was, of course, the "Russian Wheat" deal for about 10 MMT (of a total world small grain food crop of about 700 MMT in recent years). We contend that improved (earlier, more accurate) information about potential of a sizeable Soviet demand for wheat imports in world markets would have led to upward price movements earlier, say in May and June, while the deal, when completed at those new terms, would have led to a lesser price increase after this wheat transaction. The reasons for the latter effect are many, among them: (1) The possibility that at higher spot prices in July the Soviet Union might have bought less wheat (due to total budget constraints), (2) that at higher spot (and futures) prices in May and June, more would have been stored in these months, or less exported, (3) that consumption of wheat for

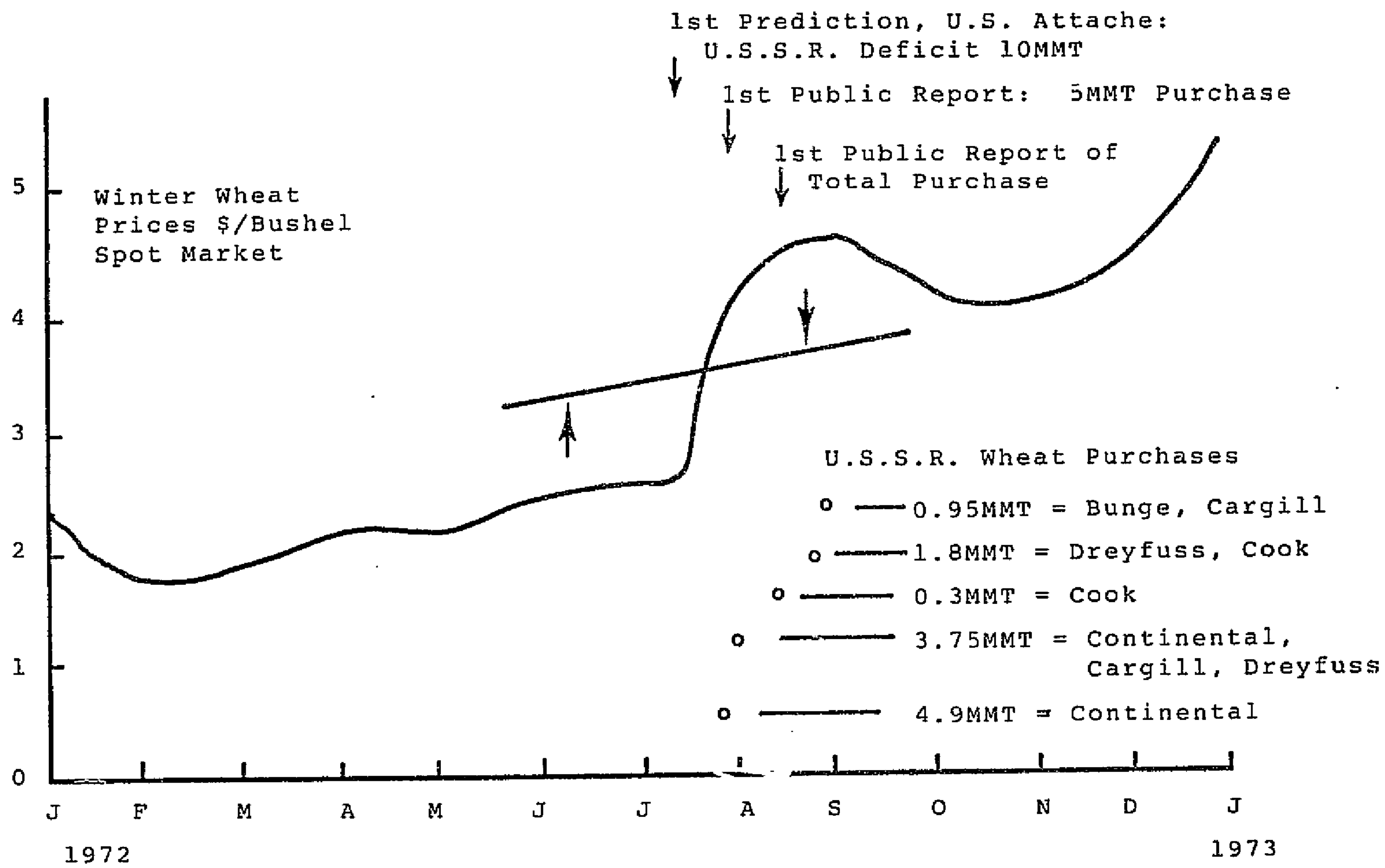

Figure 1.2 An Example of the Likely Effect of Improved Information on Wheat Prices Over Time

some uses would have receded already in May and June, rather than only later.

In the context of the above concepts of waste and resource allocation, the <u>reasons</u> for losses or waste owing to imperfect <u>specific</u> crop information are straightforward.

- Accurate forecasts allow governments and private operators to efficiently utilize existing storage, transportation, processing infrastructures and facilities.

- Timely and accurate forecasts of surpluses or shortfalls allow Government and private operators to better plan domestic and foreign transactions and policies with regard to trade, price supports and inventory holdings.

- Inaccurate crop estimates result in distorted and more volatile prices that, in turn, lead to waste and, if monetary values are a good measuring rod of satisfaction, lower levels of social welfare than would be the case if perfect information were available. [10, 11, 13, 35].

To see how this might occur in production, consider the following hypothetical, but illustrative, example pertaining to the production of wheat. A farmer, having raised a winter wheat crop and, in the presence of a forecast for a record wheat harvest, might choose not to harvest some of his wheat, but instead choose to plow some of it under for a summer crop because the incremental cost of harvesting the extra wheat was greater than the revenues the market was willing to pay him at that time. The wheat crop forecast of a record wheat harvest served to reduce the market price structure (the set of

present and future prices) of wheat since increased supply interacting with unchanged demand will depress prices. If the forecast was a gross overestimate, the farmer's correct decision would have been to harvest all of the crop as prices would have been higher in view of the true state of the world. From the consumers' point of view, prices for wheat ultimately would be forced above those that would have prevailed had the farmer not reduced supplies by plowing under part of his crop. Though occurring at different times, losses to both the farmer and the consumer could result from inaccurate crop forecasts.

1.3 Attributes and Statistical Analysis of Agricultural Information

The "information" in the title of this study refers specifically to the production of wheat in its aggregate quantitative aspects. The use of remote sensing satellites such as LANDSAT for the measurement of crop production implies a further narrowing of concepts.[1] However, to fix ideas we shall consider information about agricultural production in terms of the ongoing and future activity of crop forecasting. This is a somewhat broader viewpoint than the "measurement of crops" because it requires that the time-dependent aspects of agricultural information be taken into account. In relation to the dynamics of the market processes, it is clearly pertinent to have a time dimension to agricultural information.

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[1]Recognition of present-day limitations of the application of LANDSAT to crop acreage measurement narrows the field even more.

The attributes of information which are considered here are: availability, timeliness and accuracy. As previously analyzed,[2] these represent a convenient and comprehensive summary set of parameters in the context of economic studies of the value of agricultural information. The availability of crop forecasts and related agricultural information means: Who has access to the information at a particular time? Is it publicly available or privileged information? If it is public, is access to the publication unrestricted? If there are temporary restrictions, causing a delay in the public's access to the information, are they applied equally to all?

It has been observed that economic information, if available only to a few, can lead to distorted prices and misallocated reserves or waste. The distribution of information among market participants defines the information structure of the system. With regard to this structure, we will assume in this study that all information is equally available to all market participants and that improved information also will be available to all market participants.

The timing of the release of the crop information to the public is a closely related but separate issue. If the responsible agency were to hold back crop information until long after harvest, for example, the usefulness of that information to economic agents would be substantially diminished.

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*ECON, Inc., The Economic Value of Remote Sensing of Earth Resources from Space: An ERTS Overview and the Value of Continuity of Service, 10 Volumes, Princeton, New Jersey, December 1974.

On the other hand, information released too hastily is usually less reliable, since the very act of haste causes errors. There clearly is a right time and a right speed to apply to the publication of economically important information. All of this is built into the existing agricultural information system and would have to be reevaluated for a new system based on sound historical principles. USDA publishes its Crop Report at 3:00 p.m. on a Friday afternoon around the 20th of certain months. Forecasts of wheat production are published monthly beginning in June for all wheat, earlier for winter wheat. Year-end estimates of crop production are carefully prepared by USDA to give the public highly accurate information on major crops soon after harvest. Final revisions may be introduced into crop production estimates as late as a year after the first December report. In other countries, final estimates are available only two to three years following the harvest.

With these facts in mind, we must perceive that timeliness is a complex subject and that it is intertwined with availability and accuracy in the sense that trade offs exist between all three attributes. In our study of the published crop forecast information and its impact on the wheat market, we will treat timeliness as:

(i) a built-in institutional factor in the empirical data and

(ii) an explicit property of forecasts which can be traded off against accuracy in the somewhat oversimplified sense of Figure 1.3.

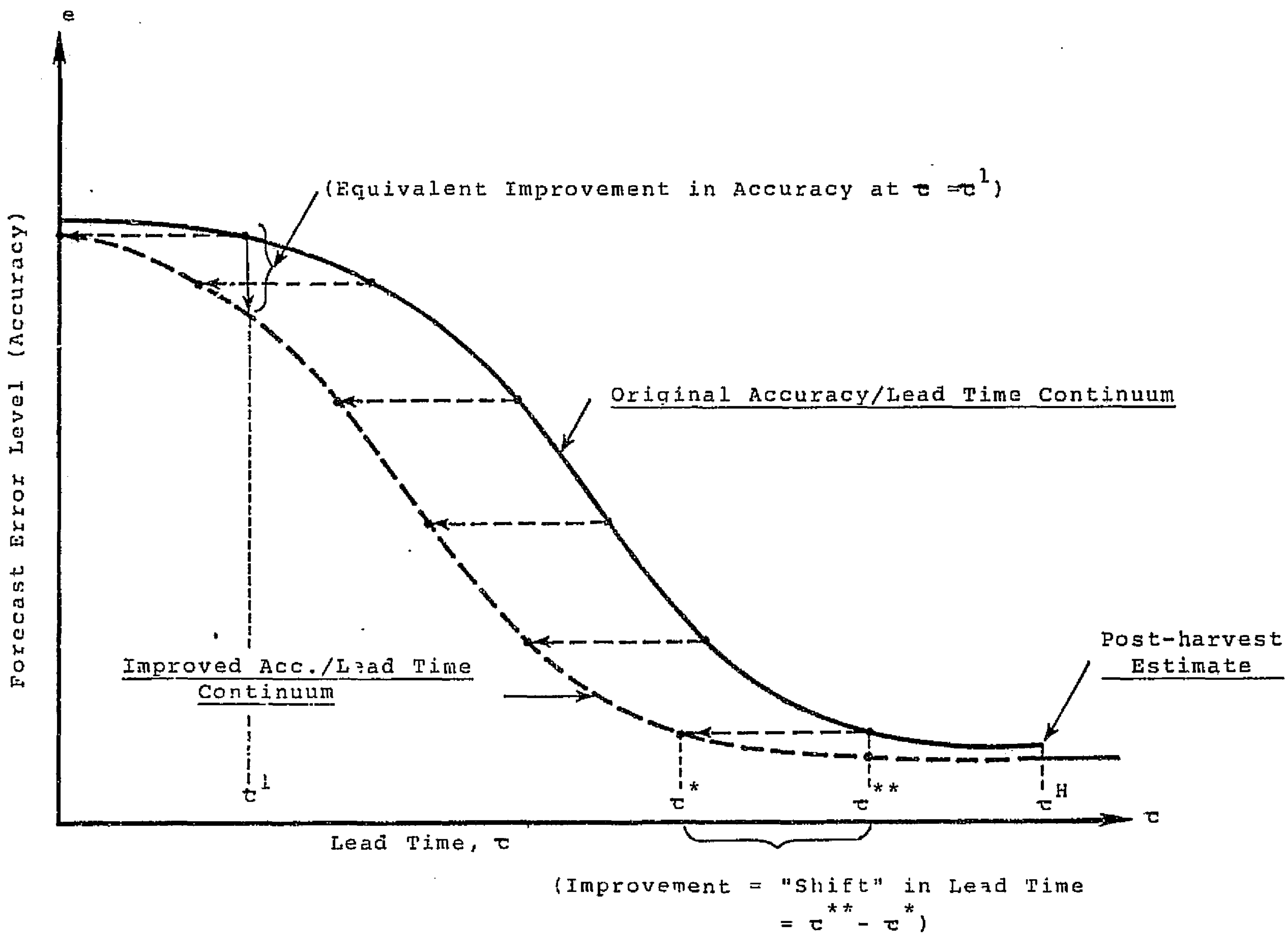

Figure 1.3 Accuracy/Lead Time Continuum Diagram

> A constant "shift" in the lead time of a sequence of forecasts corresponding to a uniform improvement of timeliness is regarded as equivalent to a calculable, but not necessarily uniform, improvement in the accuracy of all the forecasts in the sequence.

With these thoughts as a basis for our approach to the quantitative treatment of timeliness, we leave the subject for the present. A fuller discussion will be found in Chapters 3 and 4.

The third and most important attribute of crop information is its accuracy. A crop production forecast is accurate to the extent that it is not in error. This much is obvious. But how should we measure the errors in forecasts? The difficulty arises because of the impracticability of ever knowing, with perfect accuracy, the true harvest on a worldwide basis. The final estimates for each country represent the best available knowledge at the time of the true harvest in that country. These are not necessarily what is published, however! Empirical weaknesses such as the deliberate falsification by governments of their crop information are probably a fact of life about which there is nothing we can do. To the extent that they exist in the data, the statistical model may underestimate the improvement possible through a worldwide crop survey system based on LANDSAT.

In Chapter 2 we will present our detailed analysis of the accuracy of wheat production forecasting, both for currently available information and for an improved system. To obtain estimates of the accuracy of current crop forecasting

in each foreign country, we will use the final FAO production estimates as representative of the "truth." For the United States, the final revisions of all wheat production estimates, as published in the USDA publication, Crop Production, will be taken as surrogates for the true wheat harvests.

The measure of accuracy which we adopt, following a widespread practice of economics and statistics, is the variance of the error distribution. The use of the variance provides automatic bias correction for the empirical case. When modeling accuracy in a future system, we will assume unbiased forecasts throughout but there is no need to do so in relation to historical forecasts. Analysis will reveal that they have frequently shown some bias in fact.

To capture the timeliness aspect of crop forecasting which is implicit in the data, we will measure separately the accuracy of each monthly forecast and the final estimate of the annual crop production in each country. The June forecast is generally less accurate than the December estimate simply because more is know about the harvest in December. Thus we will represent the accuracy of crop forecasts for each country by a set of twelve error variances, which generally decline throughout the crop year.

1.4 The Value of Improved Crop Forecast Methods of Evaluation

The general approach to be followed in evaluating an information system -- LANDSAT with associated ground equipment

for receiving and processing the data -- which has the potential capability for achieving a worldwide improvement in crop forecasting will be outlined in this section. The point of view adopted here is that, although the technical details of the new system are not fully known, the system will be capable of generating improved forecast information on wheat production on a worldwide basis, expressed in terms of the parameters of information quality already described: availability, timeliness and accuracy.[3]

1.4.1 Outline of Modeling Approach

There are four parts to this general outline of the modeling approach:

(1) Using the Marshallian welfare concept of the integral under the demand function as in our previous benefits studies, we separate the incremental consumer surplus (B+C+D in Figure 1.4) from the incremental producer surplus (F). The direct cause of consumer and producer surpluses is an assumed downward movement in the cost of of supply function as a result of reduced uncertainty regarding future supplies. This is the "production effect" which the model uses to incorporate the many factors of economic advantage accruing from a continuous and lasting improvement in crop information. The direction of this effect (i.e. lower costs) will be confirmed by the empirical effort.

(2) Consumer and producer surpluses are calculated as quadratic forms in the old and new equilibrium prices and quantities before and after introduction of an operational LANDSAT system.

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[3] Of these, only accuracy enters our models explicitly. The other two are represented in the empirical effort, implicitly, and in the form of our assumptions.

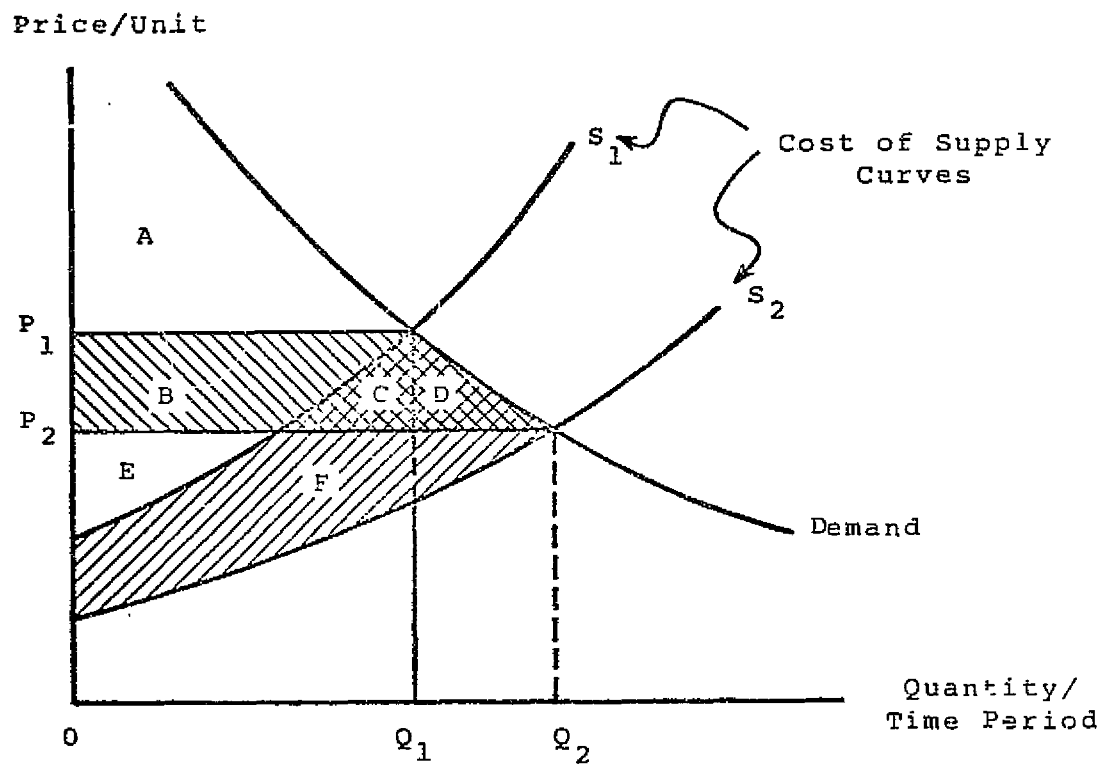


Figure 1.4 Increments in Consumer and Producer Surpluses From a Downward Shift in the Cost of Supply

The net economic effects of improved crop information will be looked at in the context of international trade. For this purpose, we assume a two-country world: the United States as the exporter, and an importing unit called "the rest of the world." The demand for wheat, both in the United States and the rest of the world, is estimated as a linear function. The demand functions play a central role in the benefits model; in particular, they determine the equilibrium trade -- exports and imports -- in this two-country world. Economic gains and losses from improved crop forecasts are calculated as incremental consumer and producer surpluses in both the United States and the rest of the world but additional benefits to the exporter (United States) can be derived from increased trade revenues. (See Figures 1.5(a) and 1.5(b) for a schematic explanation of this effect.)

(3) The impact of improved crop forecasts on the world wheat markets is modeled econometrically. Using the best available data on grain price movements, stocks and trade flows, this empirical effort arrives at estimates of the economic parameters of the market process. Equilibrium prices and quantities are then estimated by the world wheat market model for the existing state-of-crop forecasting and again for the improved system. The equilibrium estimates are based on a sequence of twenty-four consecutive months of market response to the monthly crop forecasts of wheat production on a worldwide basis.

(4) The net benefits to the United States are calculated as the algebraic sum of all consumer and producer gains and losses due to the improvement of wheat crop information. Benefits are also derived separately for consumers and producers in the United States. A similar calculation also exists for the rest of the world. However, the asymmetric aspects of the modeled situation should be kept clearly in mind: the United States is only exporter. Thus, in our model, only the United States can obtain <u>export</u> benefits due to increased or smoothed world trade patterns in wheat. The rest of the world may obtain <u>import</u> benefits as a result of the improved crop forecasts.

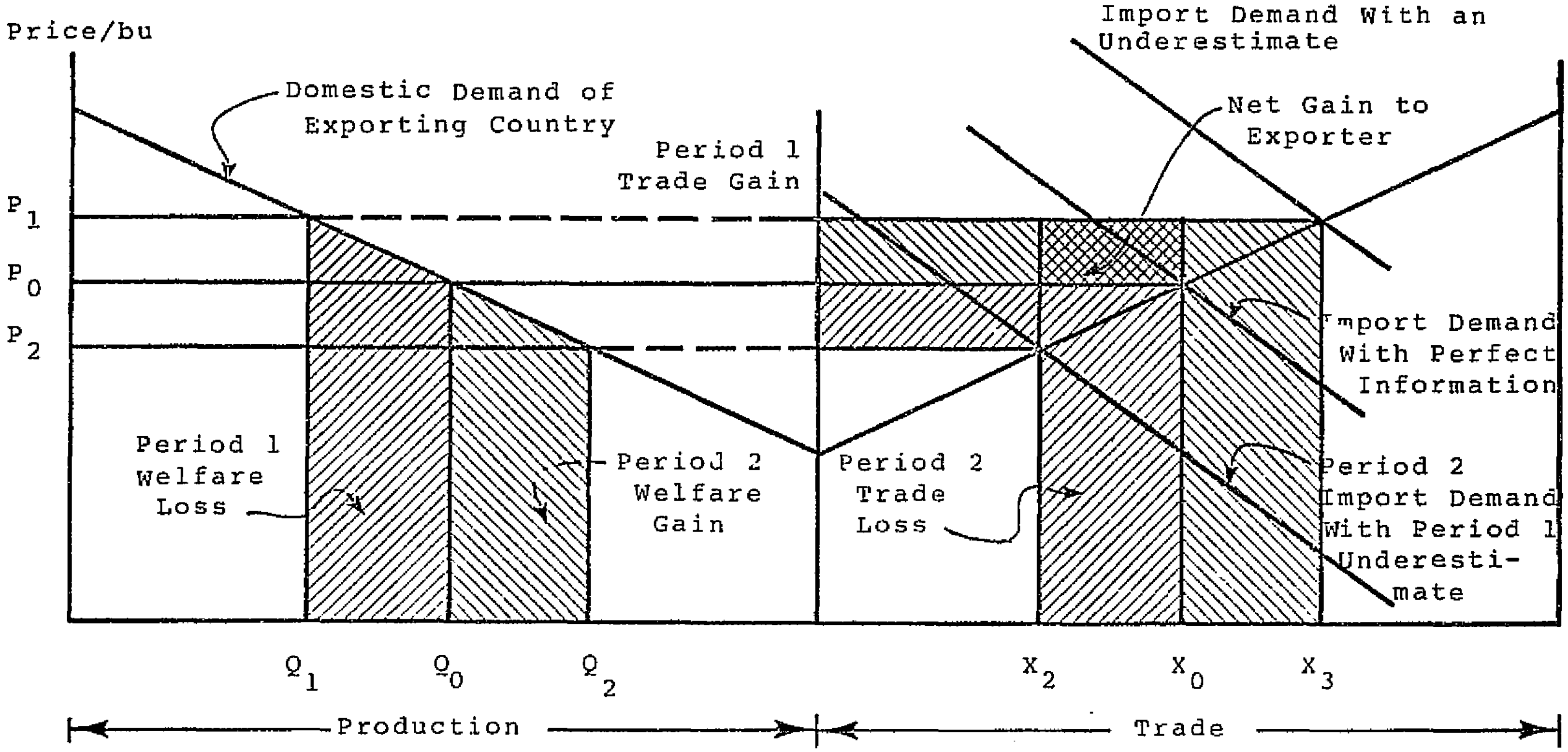


Figure 1.5 (a) Two-period Gains and Losses to an Exporting Country From a First-period Underestimation of Supply in an Importing Country

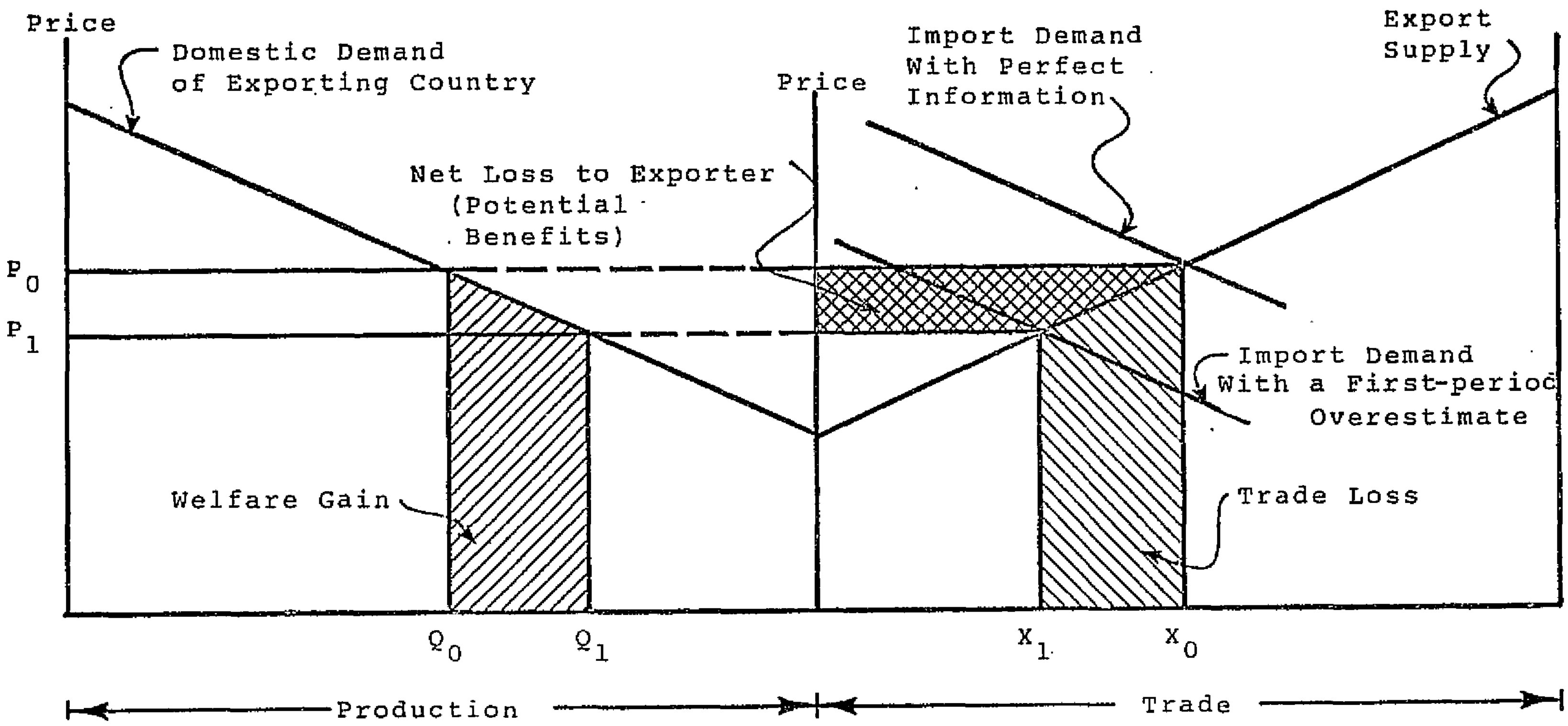


Figure 1.5 (b) Two-period Gains and Losses to an Exporting Country From a First-period Overestimation of Supply in an Importing Country

1.4.2 Dynamic Analysis of International Trade Effects

The methods of analysis outlined in the previous section do not adequately convey the dynamic processes of the market response to information. This study emphasizes the asymmetric aspects of the trade effects which other studies have previously failed to notice. There is an important difference in the benefits when the trade effects are correctly modeled as the following illustrative numerical example demonstrates.

1.4.2.1 Illustrative Two-period Example of International Trade Effects from Improved Worldwide Crop Information

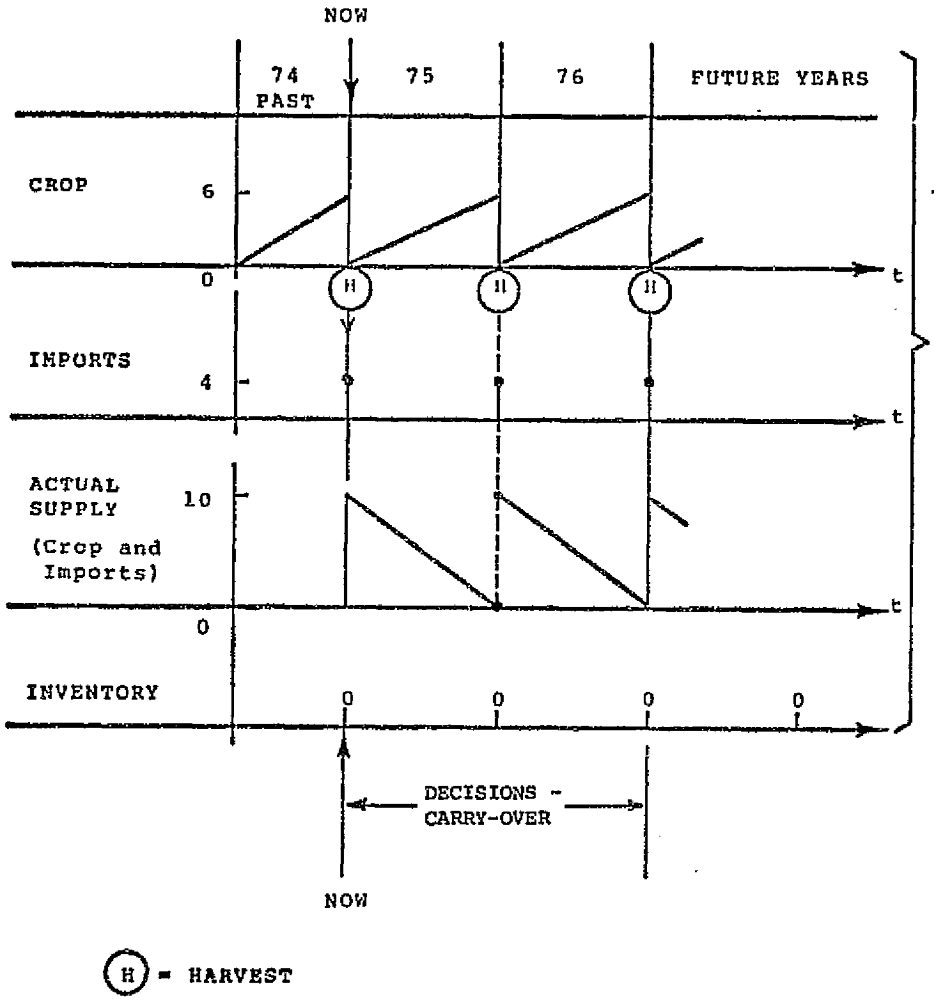
For illustrative purposes, we assume two periods -- crop years -- and two countries, one of which (U.S.) exports to the other (rest of the world -- abbreviated to "R.O.W."). Decisions to trade, and how much, are made only at the beginning of each period. Harvest occurs within each period and the world finds out any errors in crop forecasting as a result. Errors of underestimation of the importer's crop can be partially corrected in the following period by using the excess stocks to offset imports. On the contrary, it will be seen that errors of overestimation of the importer's crop cannot be corrected in the same fashion. Consumption rates in the importing country will have declined in one period and there is no compensating increase during the next period. Inventories cannot become negative and this simple fact is at the heart of the asymmetric behavior.

Figure 1.6(a) presents the essential numbers for crop production, consumption, trade and inventory under perfect information (E=o). The time chart shows the (linear) simplified patterns of consumption, crop production and actual supply within the crop year. Inventories are assumed to start at zero for this example and remain at zero under perfect information. The economic advantages of trade — a net gain to the exporter with no losses to the importer -- are depicted schematically in Figure 1.6(b).

Continuing the illustrative example, we now consider the case of a substantial negative error (E= -4) in the supply estimates for R.O.W. caused by the underestimation of the R.O.W. crop. Calculating from the same demand schedules as before, the equilibrium trade in period one is now 2 units higher than before (not 4) and in period two, after the error is discovered, there is a positive inventory of 4 units in R.O.W. Using this inventory, the R.O.W. reduces imports in period two to 2 units, giving a total two-period trade of 8 units, as before, but with a different temporal distribution. For the case of the underestimation error, detailed figures are shown in Figure 1.6(c).

The welfare effects are illustrated in Figure 1.6(d). The underestimate of R.O.W. crop causes an error of E= -4 which is reflected in swings in the trade pattern, although two-period total trade is unaffected. In this case, the United States has a net gain from the error over two periods, so

	FIRST PERIOD (1975 CROP YEAR)				SECOND PERIOD (1976 CROP YEAR)			
	DOMESTIC CROP	TRADE	SUPPLY FOR CONSUMPTION	INVENTORY FORMATION	EXPECTED CROP	TRADE	SUPPLY FOR CONSUMPTION	INVENTORY FORMATION
U.S.	14	-4	10	0	14	-4	10	0
ROW	6	+4	10	0	6	+4	10	0



TRADE

	Period 1	Period 2	Total
ERROR	T_1	T_2	T
ZERO	4	4	8

Figure 1.6(a) Rest of the World Decisions Under Perfect Information (E=0)

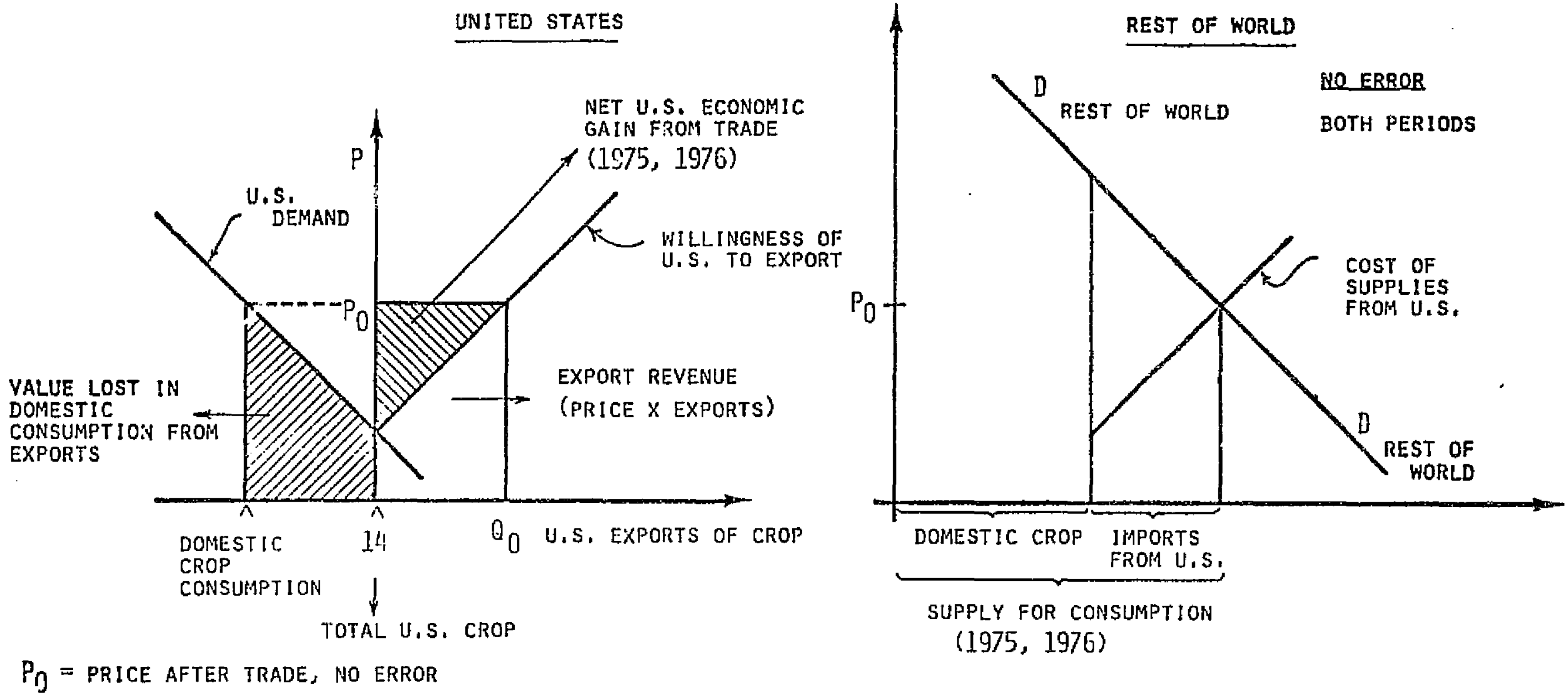
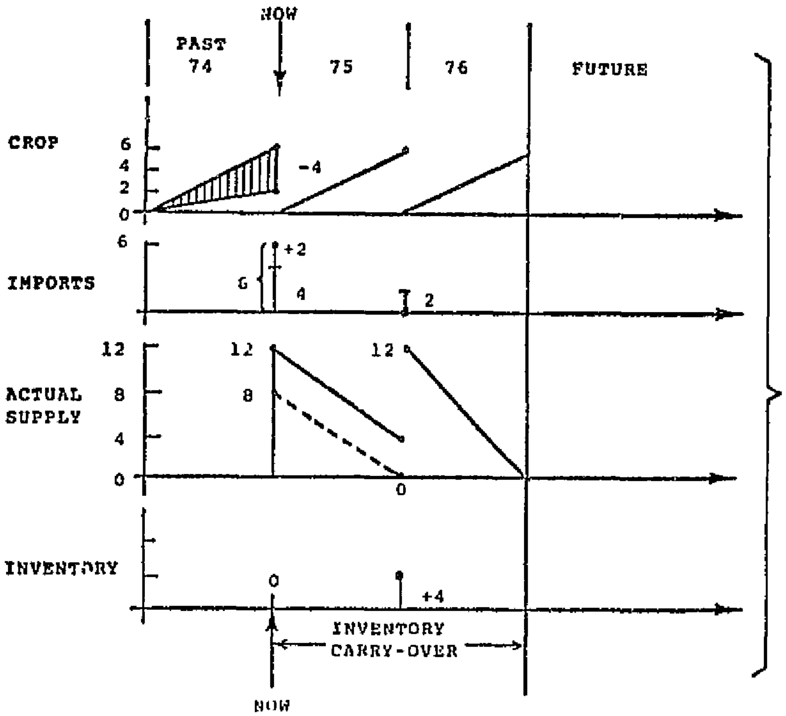


Figure 1.6(b) Benefits to Exporting Country (no error: E=0)

	FIRST PERIOD				SECOND PERIOD			
	E(CROP)	TRADE	SUPPLY FOR CONSUMPTION	INVENTORY FORMATION	EXPECTED CROP	AVAILABLE INVENTORY	TRADE	SUPPLY FOR CONSUMPTION
U.S.	14	-6	8		14		-2	12
ROW	2	+6	8	+4	6	4	+2	12



TRADE

	Period 1	Period 2	Total
ERROR	T_1	T_2	T
E = -4	6	2	8

Figure 1.6(c) Underestimate of R.O.W. Crop (E= -4)

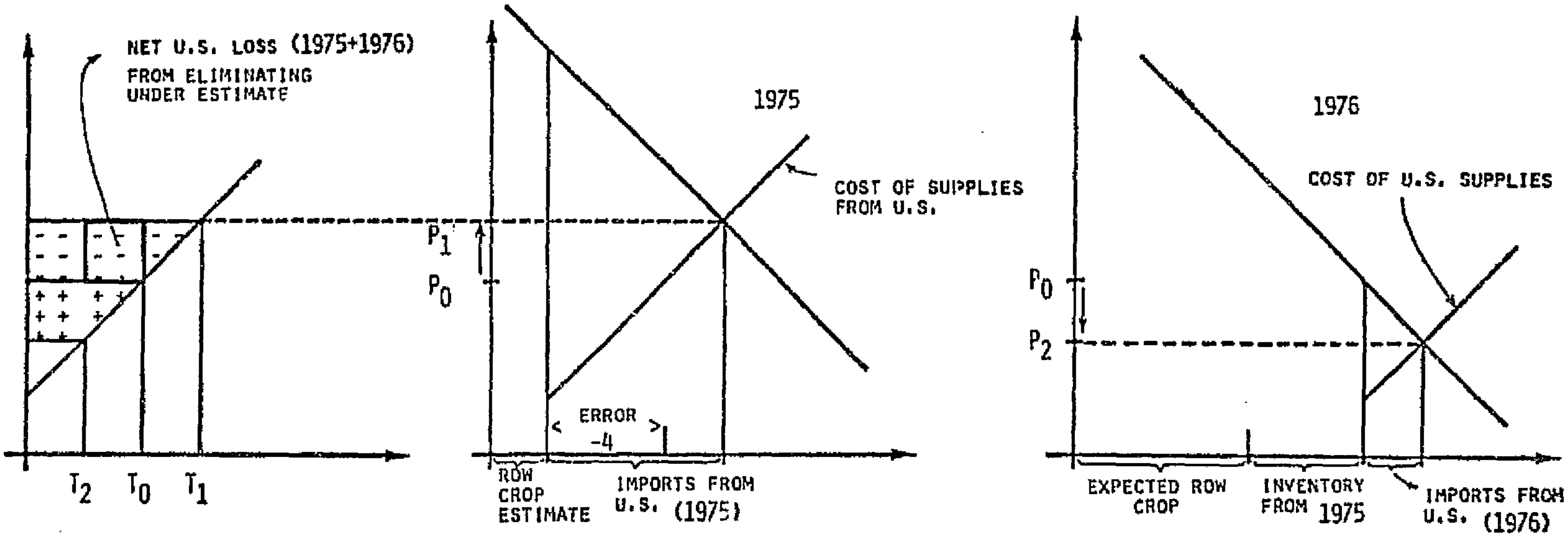


Figure 1.6(d) Net U.S. Loss From Elimination of Underestimates

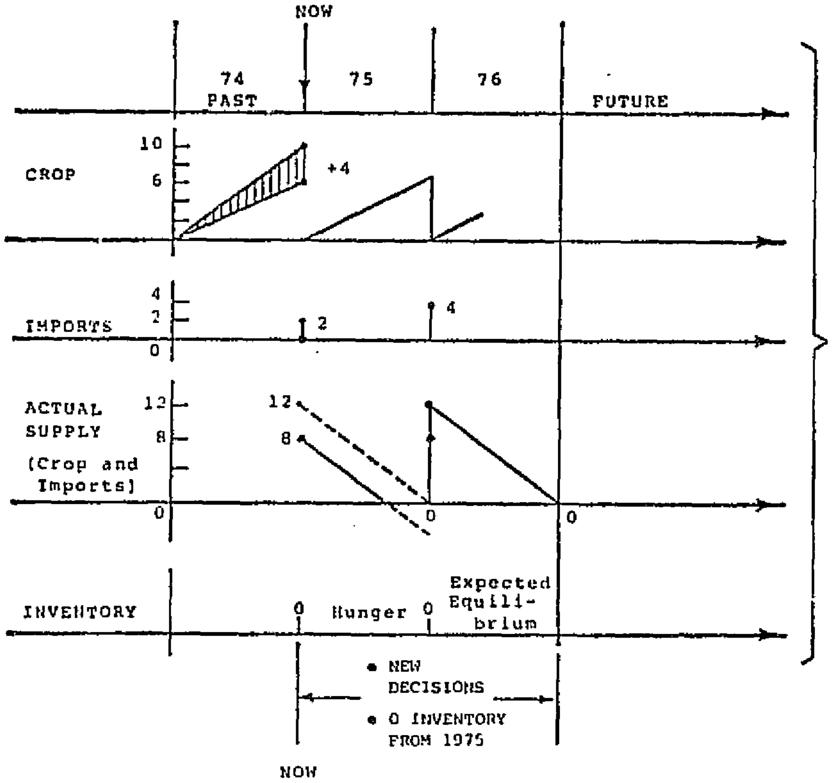
there would be a resultant United States <u>loss</u> if the error were to be completely eliminated.

Following the analysis in similar manner for the case of an overestimate of R.O.W. crop production in period one, we assume (symmetrically) an error of E= +4 units in the R.O.W. supply estimate for period two. The R.O.W. import decision, under our strict assumptions, is to import only 2 units in period one. When the harvest comes in, the shortage is discovered but it is too late to do anything about it within the period. Since there are no "negative inventories," the mistake is not corrected in period two when we assume things return to normal. Total trade for both periods is down by 2 units and R.O.W. has suffered the shortages mentioned above.

The details of the overestimation case are shown in Figure 1.6(e). Turning to the welfare effects, shown schematically in Figure 1.6(f), we see that there is a net United States loss due to the overestimate: this is associated with the reduced total volume of exports (6 units as compared with 8) within two full periods. By eliminating overestimation errors completely, one would accordingly establish a net United States gain as shown in the diagram on the left of Figure 1.6(f).

For completion of the example, it is only necessary to consider the combination of economic effects from both types of error. At this level of discussion, there is no reason to suppose one type more prevalent than the other (if it were so

	FIRST PERIOD				SECOND PERIOD			
	E(CROP)	TRADE	ACTUAL CROP	SUPPLY FOR CONSUMPTION	EXPECTED CROP	TRADE	SUPPLY	INVENTORY FORMATION
U.S.	14	-2	14	12	14	-4	10	0
ROW	10	+2	6	8 (RELATIVE HUNGER)	6	+4	10	0



TRADE

	Period 1	Period 2	Total
ERROR	T_1	T_2	T
E = +4	2	4	6

Figure 1.6(e) Overestimate of R.O.W. Crop (E= +4)

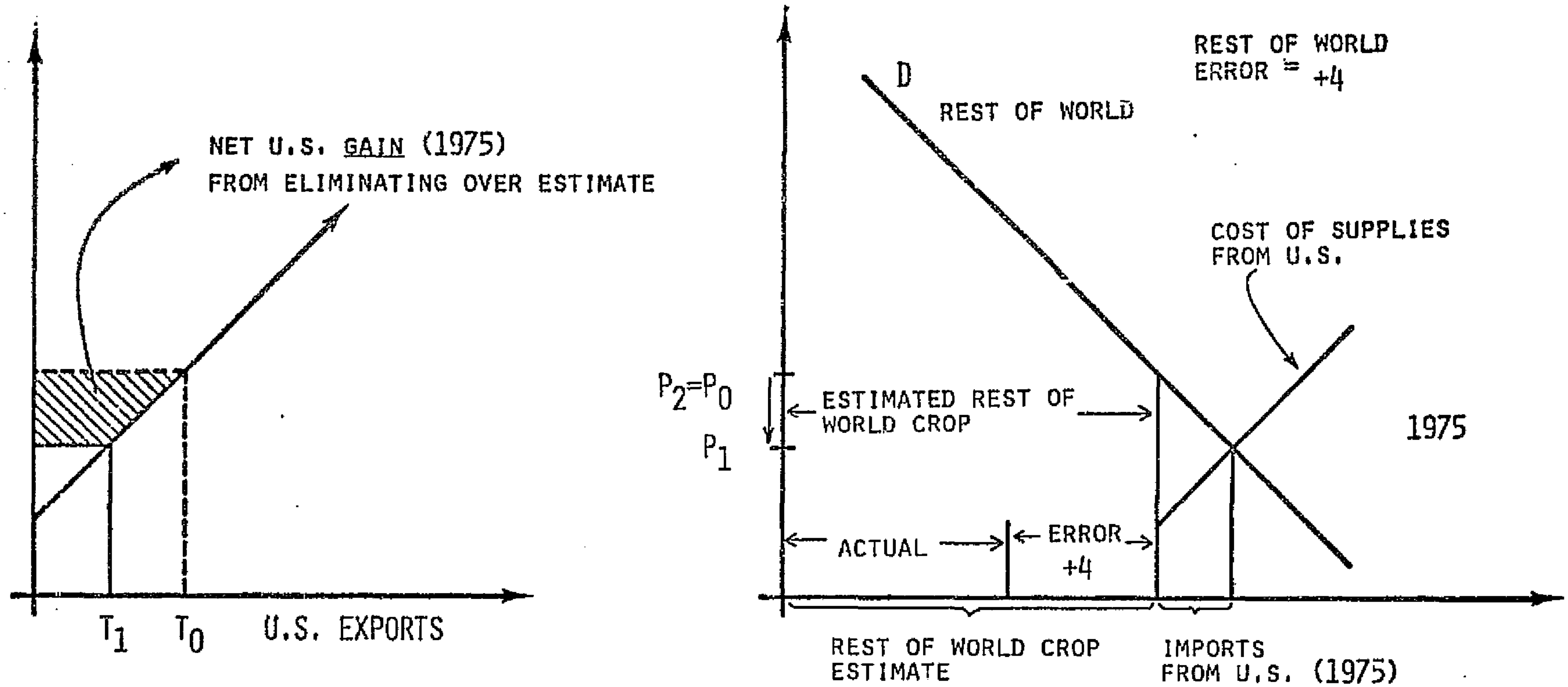


Figure 1.6(f) Net United States Gain From Elimination of Overestimation Error

this would not alter the trend of the argument), so we take each error with one half weight. The full treatment of the subject (see Chapter 2) would of course take into account a distribution of errors. Nevertheless, the basic point is made in this simple example that the expected value resulting from eliminating both over and underestimation errors in crop forecasts is a net (trade) benefit to the United States. Figure 1.6(g) shows the whole sequence of welfare charts leading up to the final chart on the lower right which presents the combined effect for the United States: a net gain of 1 unit over both periods in the average.

The example does not consider welfare effects for the rest of the world, nor does it attempt realism in relation to how price movements would occur over time: we leave these and numerous other details to Chapters 3 and 4. Nevertheless, the numbers presented in the example have meaning and are derived from sound economic assumptions which are summarized in Figure 1.6(h) for the sake of completeness. It has indicated that the asymmetric economic behavior of importing countries with respect to equal over and underestimation errors, results in two-period average net gains to the exporting country (in our model this refers only to the United States). The argument is valid if the decision period is a quarter or a month and the same type of asymmetric trade effect -- only with different absolute magnitude -- will be observed. To verify this claim, a small computer simulation was run of the

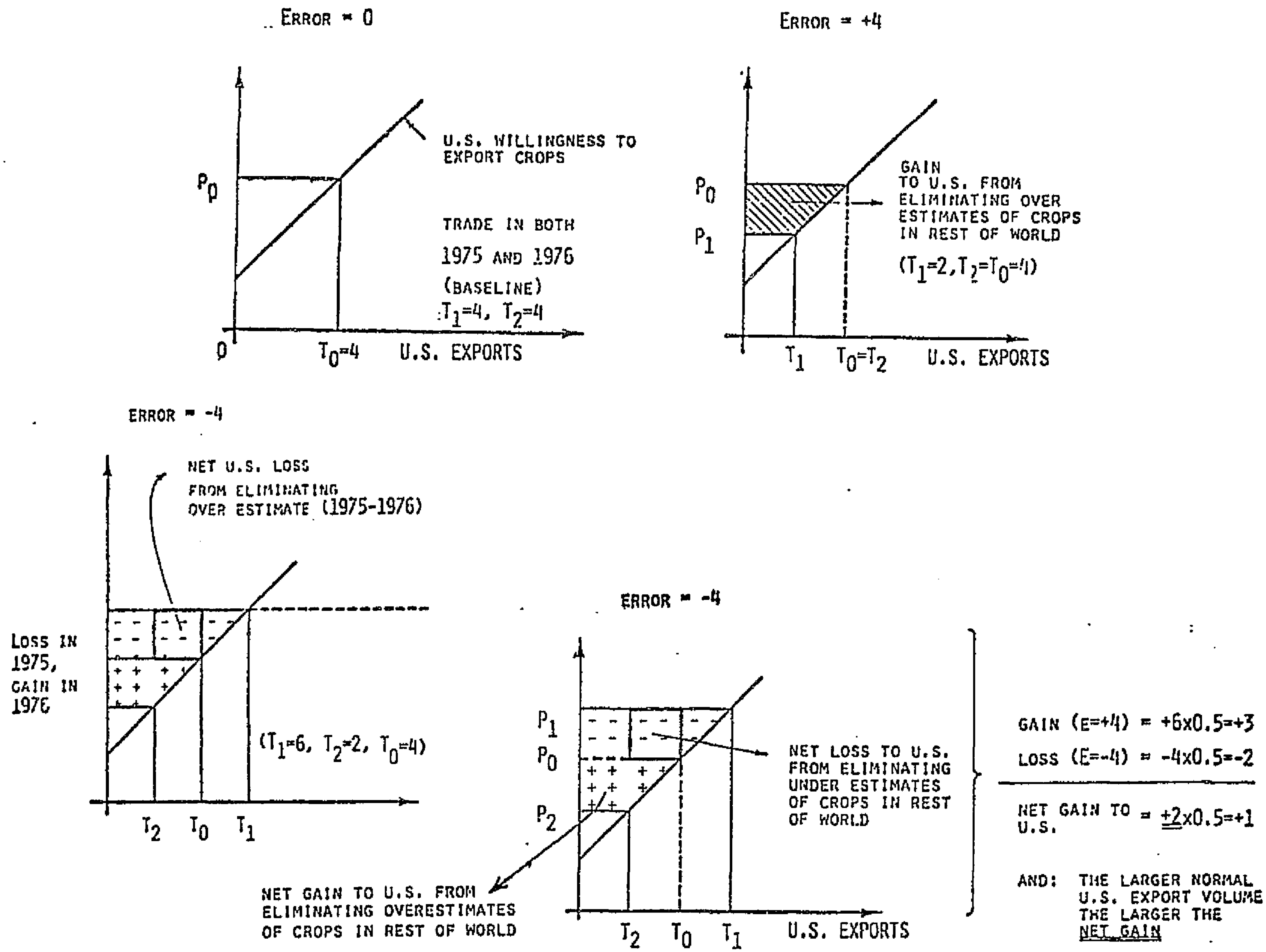


Figure 1.6(g) Net Gain to United States From Elimination of Both Over and Underestimation Errors

asymmetric trade effect using random errors with two percent standard deviation over 40 consecutive periods.[4] The net average United States gain was calculated based on assumed 50 percent level for United States exports as a fraction of United States production. With a conventional estimated value of United States demand elasticity at -0.5, the result is $241 million if the R.O.W. is completely price inelastic (at equilibrium prices and supply) in their demand for grain. When we assumed that R.O.W. had the same demand elasticity as the United States, the net average gain to the United States was $123 million. The main point of this simulation exercise is to demonstrate clearly that the effect is not due to the simplified treatment of errors of estimation in the illustrative two-period example.

---

[4]The detailed assumptions, data and results of the simulation exercise are appended to this chapter. We can regard the periods as years without violating the assumptions of this exercise, if we are willing to ignore the effects of long-term shifts in demand and supply for 40 years.

- CROP MEASUREMENT ERROR IN REST OF WORLD ONLY $\begin{cases} E = 0 \\ E = -4 \\ E = +4 \end{cases}$
- FREE TRADE CASE
- CONSTRAINT: INVENTORIES ≥ 0
- ACTUAL CROPS: (ACTUAL CROPS)
  U.S. = 14 UNITS
  ROW = 6 UNITS
- DEMAND ELASTICITIES AT POINT OF MEASUREMENT: U.S. = - .5
  ROW = - .5
- DATE: DAY 1 OF MONTH 1 OF 1975 CROP YEAR
- YEARLY DECISIONS

Figure 1.6 (h) Assumptions Used in Illustrative Two-Period Example

APPENDIX TO CHAPTER 1:
SIMULATION OF ASYMMETRIC TRADE EFFECTS

ASYMMETRIC TRADE EFFECTS FOR OVER-AND UNDER-SIMULATION ESTIMATION ERRORS: SMALL COMPUTER

R - FLATLY DISTRIBUTED RANDOM VARIABLE (0-99)

T - TOTAL ANNUAL FOOD EXPORT, EQUIVALENT MMT OF GRAIN, GIVEN PERFECT INFORMATION

M - MEASUREMENT ERROR, FRACTION OF T

I - INVENTORY - IN ROW, FRACTION OF T

Δt - CHANGE IN U.S. EXPORTS DUE TO IMPERFECT INFORMATION, FRACTION OF T

G - GAIN TO U.S. FROM INFORMATION IMPROVEMENT ON ROW CROPS

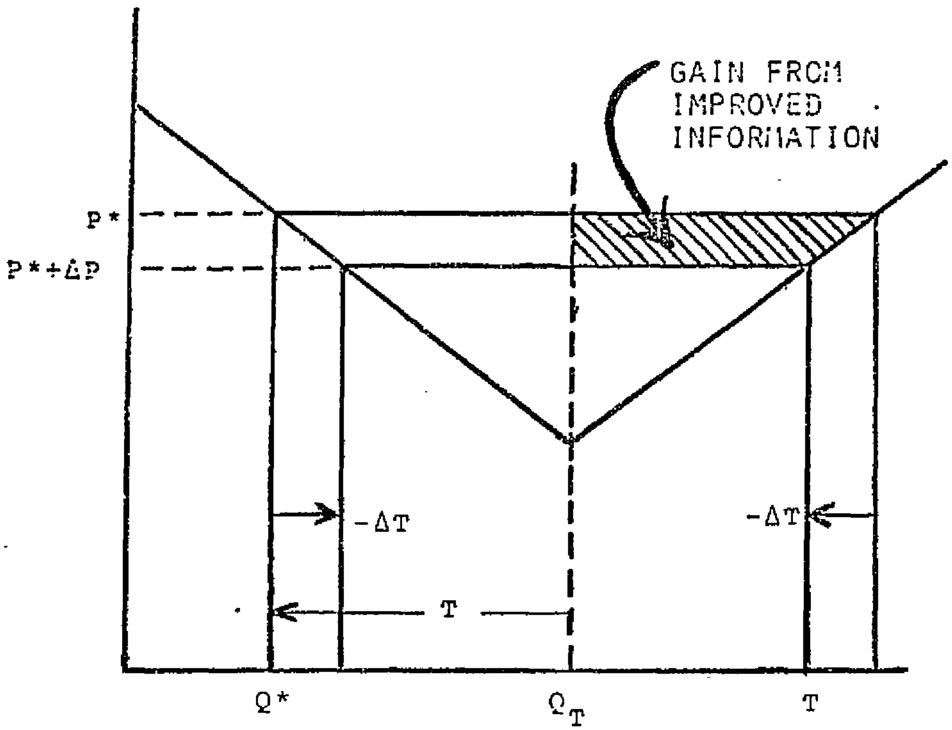
P^* - U.S. PRICE, PERFECT INFORMATION

Q^* - U.S. CONSUMPTION, PERFECT INFORMATION

$e_{U.S.}$ - ELASTICITY OF U.S. DEMAND FOR CROP AT P^*, Q^*

e_{ROW} - ELASTICITY OF ROW DEMAND FOR CROP AT P^*, Q^*_{ROW}

DERIVATION OF GAIN FROM IMPROVED INFORMATION



IN ANY YEAR:

$$G = \frac{1}{2}\,(T+T+\Delta T)\,\Delta P$$

WHERE $\Delta P = -\frac{(\Delta T)P^*}{e_{US}Q^*}$ $\left(\Delta Q = -\Delta T,\ e_{US}<0\right)$

$$G = +\left(T+\frac{\Delta T}{2}\right)\frac{(\Delta T)P^*}{e_{US}Q^*}$$

NORMALIZE $\Delta t = \Delta T/T$

$$G = \frac{T^2P^*}{e_{US}Q^*}\left(\Delta t+\frac{\Delta t^2}{2}\right)$$

IF Δt IS NEGATIVE, G IS POSITIVE (FOR $-2<\Delta t<0$)

IF Δt IS POSITIVE, G IS NEGATIVE

ANNUAL GAIN OVER MANY YEARS

IN ANY YEAR:

$$G = \frac{T^2 P^*}{e_{U.S.} Q^*} \left(\Delta t + \frac{\Delta t^2}{2}\right)$$

AVERAGE OVER MANY YEARS

$$\overline{G} = \frac{T^2 P^*}{e_{U.S.} Q^*} \left(\overline{\Delta t} + \overline{\frac{\Delta t^2}{2}}\right)$$

IF $\overline{\Delta t}$ IS NEGATIVE, $\overline{G}$ IS POSITIVE (FOR $-2 < \Delta t < 0$)

RESULTS OF COMPUTER SIMULATION FOR 40 SEQUENTIAL PERIODS

RANDOM VARIABLE (0-99) R	ROW MEASUREMENT ERROR $M(\sigma = .02)$	INVENTORY IN ROW I	CHANGE IN U.S. TRADE Δt $e_{row} = 0$	$e_{row} = -0.5$
13	-.0226	.0226		+.0113
10	-.0258	.0258	+.0032	+.0016
62	.0062	0	-.0320	-.0160
67	.0088	0	-.0088	-.0044
55	.0026	0	-.0026	-.0013
78	.0156	0	-.0156	-.0078
64	..0072	0	-.0072	-.0036
20	-.0170	.0170	+.0170	+.0085
91	.0270	0	-.0440	-.0220
36	-.0072	.0072	+.0072	+.0036
96	.0350	0	-.0422	-.0211
36	-.0072	.0072	+.0072	+.0036
39	-.0056	.0056	-.0016	-.0008
15	-.0208	.0208	+.0152	+.0076
27	-.0124	.0124	-.0084	-.0042
45	-.0026	.0026	-.0098	-.0049
25	-.0136	.0136	-.0110	-.0055
55	.0026	0	-.0162	-.0081
73	.0124	0	-.0124	-.0062
75	.0136	0	-.0136	-.0068

RESULTS OF COMPUTER SIMULATION FOR 40 SEQUENTIAL PERIODS (continued)

RANDOM VARIABLE (0-99) R	ROW MEASUREMENT ERROR M(σ=.02)	INVENTORY IN ROW I	CHANGE IN U.S. TRADE Δt $e_{row}=0$	$e_{row}=-0.5$
12	-.0236	.0236	+.0236	+.0118
95	.0330	0	-.0566	-.0283
58	.0042	0	-.0042	-.0021
22	-.0156	.0156	+.0156	+.0078
29	-.0112	.0112	-.0044	-.0022
07	-.0296	.0296	+.0184	+.0092
27	-.0124	.0124	-.0172	-.0086
46	-.0022	.0022	-.0102	-.0051
03	-.0376	.0376	+.0354	+.0177
57	.0036	0	-.0412	-.0206
86	.0218	0	-.0218	-.0109
97	.0376	0	-.0376	-.0188
11	-.0246	.0246	+.0246	+.0123
76	.0142	0	-.0388	-.0194
51	.0006	0	-.0006	-.0003
94	.0312	0	-.0312	-.0156
24	-.0142	.0142	+.0142	+.0071
47	-.0016	.0016	-.0126	-.0063
53	.0016	0	-.0032	-.0016
72	.0118	0	-.0118	-.0059

SUMMARY OF U.S. GAINS FROM ASYMMETRIC TRADE EFFECTS

RESULTS OF SIMULATION

ANCILLARY ORDER OF MAGNITUDE DATA:

$Q^* = 100$ MMT

$P^* = \$160$/MT

$T = 100$ MMT (I.E., 50% OF TOTAL U.S. PRODUCTION)

CASE 1.

$e_{U.S.} = -0.5$ AT P^*, Q^*

$e_{ROW} = 0$ AT P^*, Q^*_{ROW}

$\overline{\Delta t} = -0.0078$

$\overline{\Delta t^2} = 0.00051$

$\overline{G} = \$241$ M

CASE 2.

$e_{U.S.} = -0.5$ AT P^*, Q^*

$e_{ROW} = -0.5$ AT P^*, Q^*_{ROW}

$\overline{\Delta t} = -0.0039$

$\overline{\Delta t^2} = 0.00013$

$\overline{G} = \$123$ M

2. CROP INFORMATION

2.1 Wheat Production Forecasts: Current Knowledge

A full discussion of the methods of wheat production measurement and forecasting would occupy a volume as large as this entire report. The present section will only deal with selected aspects of the subject: (i) sources of forecast information on wheat, (ii) the causes of forecast error in the United States, and (iii) analytical methods for deriving useful statistics of forecast errors in the United States and the Rest of the World today. The analytical requirements of the present study of benefits from improved crop information lead to a specialized technical point of view toward the statistical analysis. The major numerical results are variances of monthly wheat production forecasts for eleven major wheat-producing countries before and after introduction of an operational LANDSAT system. Since these statistics are an original contribution of the present study, they will be presented in Section 2.3 as part of the modeling approach. Accuracy of wheat forecasts and their error distributions will be discussed in general terms in the present section.

2.1.1. Background: Crop Measurement and Reporting

The measurement of crops - at planting and at harvest is necessary for planning and decision-making in agricultural commodity firms, in governmental agencies and on the farms which produce the crops. Crop production reporting at state or national

levels forms the basis for market and stocking decisions which, in turn, influence prices and supplies of commodities. Service industries, e.g., those providing storage facilities or transportation for commodities need to know crop production statistics for proper management of business planning. The farmer who is considering whether to plant soybeans or grains in his acreage is interested in crop statistics (prices, acreage, etc.) to guide his decision. The administrator of a PL480 program, distributing food products to assist countries with severe shortages, needs to have estimates of crop production in those countries.

Crop reporting by USDA, as we know it today, has evolved over the last 100 years. The scientific sampling of U.S. farms, the use of regression models for forecasting and estimation, and the development of computerized techniques for processing the large amount of data collected, have all been introduced to improve crop reporting in the last twenty-five years.

A crop forecast, as viewed by the USDA Statistical Reporting Service,[5] is distinguished from an estimate in that: "forecasts relate to an expected future occurrence, such as crop yields prior to actual harvest of the crop." Both forecasts and estimates of wheat production in the U.S. and Rest of the World are useful in the agricultural community and necessary for the present study. The accuracy of wheat production forecasts in the available published sources will be reviewed in

[5] Scope and Methods of the Statistical Reporting Service, USDA Miscellaneous Publication No. 1308, November 1975.

the following pages in order to prepare estimates of the accuracy of the baseline crop reporting "information system," i.e., without the use of operational remote sensing of crops from space. The sources of statistical data are listed in Table 2.1. For the United States, the USDA publication Crop Production (K) was used as a source both of forecasts, for all wheat of annual U.S. production, and of final estimates of the same quantities. Wheat production forecasts for foreign countries were obtained mainly from the Grain Bulletin (F) published monthly in the U.K. by the Commonwealth Secretariat. Final estimates of true wheat production by country for the years 1960 to 1974 were obtained from FAO Production Yearbook (A).

Although some uncertaintly exists concerning the true final wheat production in many foreign countries, even long after the harvest is complete, it must be stated that the USDA is widely acknowledged to be the source of the most comprehensive and accurate information on crop production. Thus it is of interest to consider the goals and achievements of USDA as a model of excellence. For the year-end annual crop production estimates, the USDA goal on a national scale is to be within ±2 percent for major crops. Analysis[6] of actual forecast accuracies shows that, for the period 1929-1970, only the November forecast for corn and the August forecast for winter wheat met this goal on the average. However, improvements have been

[6] Gunnelson, G., W. D. Dodson and S. Pamperin: "Analysis of the Accuracy of USDA Crop Forecast," Journal of Agricultural Economics, November 1972, pp. 639-645.

Table 2.1 Sources of Statistical Information on Crops

Code	Source
A	FAO Production Yearbook
B	FAO Trade Yearbook
C	FAO Monthly Bulletin
D	IWC World Wheat Statistics
E	IWC Review of World Wheat Situation
F	Grain Bulletin, Commonwealth Secretariat
G	Commodity Research Bureau Commodity Yearbook
H	Foreign Agriculture Service Foreign Agriculture Circular, FG 10-74 April 1974
I	USDA Food Grain Statistics various issues
J	IMF International Financial Statistics
K	USDA Crop Production various issues from 1959 to 1975
L	FAS World Demand Prospects for Wheat in 1980 Report #62
M	UN Demographic Yearbook
N	Chicago Board of Trade Statistical Supplement
O	FAS World Grain Trade Statistics

made since 1970 in USDA crop forecasting, and it should be mentioned that the stated goals were not adopted until the 1960s. The well known results of the 1972 analysis by Gunnelson et. al. are summarized in Table 2.2. To supplement this analysis we performed a similar study (for wheat only) of the forecasts published in the Grain Bulletin for the U.S. in the years 1960 to 1974. The results shown in Table 2.3 are roughly the same order of magnitude if one takes into account that our statistics comprise all wheat, whereas Gunnelson et. al., studied winter wheat and spring wheat separately.

2.1.2 State of Crop Forecasting: United States

There are several causes of error in U.S. crop production forecasts[7]. The forecasts are based on estimates of crop acreages in the United States and separate determinations of crop yield, by crop reporting district (CRD). The forecasting method relies on an assumption that weather, diseases and insect infestation (i.e., causes of crop losses) will be "average" during the time remaining after the forecast until harvest. Departures from the average, which is taken with respect to the most recent years for which data are available, inevitably result in errors in the forecast. The various types of error in U.S. crop production forecasts are listed in Table 2.4 below, and these must be considered within the context of the

[7] The errors in crop forecasting to which we refer are statistical in nature, not procedural. They do not invalidate the usefulness of the forecasts.

Table 2.2 Size of Average Absolute Percentage Forecasting Error in USDA Crop Forecasts by Commodity and Forecast Month, 1929-1970[a]

Commodity	Absolute Error by Forecast Month								
	December	April	May	June	July	August	September	October	November
		(Percentages)							
Barley					7.1	3.1	2.2		
Corn					9.2	5.9	4.0	2.8	2.0
Oats					4.9	2.9	2.4		
Potatoes						5.5	4.5	3.2	2.6
Soybeans						5.6[b]	5.1[c]	3.7[c]	2.9[c]
Spring Wheat					10.7	6.7	3.0	2.8	
Winter Wheat[d]	11.5	8.5	7.6	6.9	4.0	2.1			

[a]Forecasting error equals the absolute difference between the forecast and the December revised estimate expressed as a percentage of the December revised estimate.

[b]Percentages computed from data for 1944-1970.

[c]Percentages computed from data for 1940-1970.

[d]Error percentages for December winter wheat forecasts computed from data for 1942-1970. Error percentages for other winter wheat forecast months computed from 1920-1970 data.

Source: G. Gunnelson, W.D. Dobson and S. Pamperin: An Analysis of the Accuracy of USDA Crop Forecasts, American Journal of Agricultural Economics, November 1972.

Table 2.3 Standard Deviation of U.S. Monthly Wheat "Forecast" Errors* (1959 - 1974)

"Forecast" Month	Standard Deviation of Percentage Forecast Error
May	8.78
June	8.11
July	3.38
August	1.98
September	1.89
October	1.35
November	1.35
December	0.68
January	0.68
February	0.68
March	0.68
April	0.68

Source: ECON analysis of Crop Production forecasts and estimates for years 1959-1974.

* The published estimates of wheat production are not all proper forecasts since some are published after harvest.

Table 2.4 Types of Error in U.S. Crop Forecasts

FORECAST OR ESTIMATE OF	REPORTING CYCLE	TYPES OF ERROR SOURCE
• MONTHLY U.S. CROP • ANNUAL U.S. CROP* • MONTHLY STATE OR REGIONAL CROP • ANNUAL STATE OR REGIONAL CROP	• MONTHLY* • ANNUAL	(1) FORECAST (BEFORE HARVEST)* • RANDOMNESS OF NATURE • CROP MEASUREMENT ERROR - ACREAGE - YIELD • TIME LAG BETWEEN MEASUREMENT AND FORECAST • FORECAST ERROR "PER SE" (EVEN WITH PERFECT INFORMATION) (2) HARVEST MEASUREMENT ERROR (AT HARVEST) • CROP MEASUREMENT ERROR - ACREAGE - YIELD • TIME LAG UNTIL REPORTED

*USDA/SRS practice

quantity to be forecast - whether regional or national, monthly or annual etc. - and the release or publication deadlines for the crop forecast. Some errors are statistical in nature and can only be reduced by increasing sample size or precision of measurements, which implies increased cost of crop forecasting. Other errors, such as those due to "randomness of nature," are unavoidable, a fact of life.

Basic types of error in the crop acreage estimates are:

> Sampling Error, which is due to the "unrepresentative" character of the sample of farmlands selected as a basis for estimating acreage planted in the crop (of course the sample selection process is designed to obtain as nearly representative sample as possible)
>
> Measurement Error, which is due to the imperfections of measuring the acreage selected for inclusion in the sample
>
> Difference Between Planted and Harvested Acreages. The acreage planted is not the truly relevant quantity since crop production clearly depends on the acreage harvested, which cannot be known at the time when most forecasting is done. Thus, we must also record the difference between acreage planted (the potential harvest acreage) and acreage harvested as an unavoidable source of error. It will be reduced by monitoring crop acreage right up to harvest, but it will not be completely eliminated in all cases.

Although we have referred to the first three types of error as basic, the use of a good sample and the choice of a scientific measurement technique will help to keep errors of sampling and measurement to a minimum. In the case of errors due to the difference between crop acreage planted and crop acreage harvested, analysis of the reasons for crop abandonment,

e.g., sudden frost, can permit revision of the estimates when those reasons are known. Obviously this will not always be the case.

In addition to the basic errors, there are also minor or occasional sources of error which are as follows:

- recording errors, i.e., mistakes or mechanical errors
- subjectivity in parts of the estimation program
- unavailability of some of the sample data, e.g., nonresponse in questionnaire mail-out.

Although these sources of error clearly exist, they are not a serious problem, insofar as their effects can easily be reduced to acceptable proportions. They will not be considered further in the present discussion, since they are not relevant to the issue of improved worldwide agricultural crop statistics using remote sensing from space.

2.1.3. State of Crop Forecasting: Foreign Agriculture

The agricultural statistics from other countries vary enormously in quality, timeliness and comprehensiveness. In many cases they are not based on scientific sampling and measurement procedures and so cannot be considered in the same framework of error analysis applied to the United States. Furthermore, there does not appear to exist any reliable measure of the accuracy of most foreign crop survey statistics since it is hard to determine the true crop production even long after the event. To make matters worse, the deliberate falsification of publicly released crop production figures by some governments

is strongly indicated.

Crop production forecast accuracies for individual countries and regions were calculated using FAO final harvest figures and a mixture of official and naive crop forecasts. The FAO final harvest figures typically are reported two to three years after the harvest. Using these "final" figures as the actual production quantity, Root Mean Square (RMS) forecast and revision errors were calculated. Specifically RMS errors were calculated for each country for eleven months prior to harvest completion, the month in which the harvest was completed and for twelve months after the harvest was completed. This was done using the 1960 to 1974 FAO Production Yearbook and Commonwealth Secretariat's Grain Bulletin wheat data.

The production forecast figures consist of official forecasts and naive forecasts. The official forecasts are those made by official agencies, departments or institutions in each country or region. Often these forecasts are made in the harvest month. However, the marketplace does not have the luxury of ignoring the likely or possible outcome prior to harvest. In order to fill their information void, "naive" crop forecasts were constructed for those months prior to harvest and in which official forecasts are not made. The naive forecasts were constructed using a five year moving average of past crop forecasts. This mechanism was used for two reasons. First, it uses data available to the marketplace; second, it tends to average out extreme harvests. Suprisingly, these forecasts, on

average are more accurate than the first official forecast for many countries and are not far off from the first official forecast in any country except those few where the forecast is made in the harvest month.

Insofar as the world market for wheat exhibits relatively free trade, it is the world production and its forecasts that are of ultimate economic concern. The world production and its forecasts of course are made up of individual country productions and their forecasts. This study uses the eleven major wheat producting countries[8] for which monthly production forecasts are published on a fairly consistent basis in the Grain Bulletin. The aggregate production of the ten non-U.S. countries represents about 70 percent of non-U.S. world wheat production.

The forecasts for these ten countries were combined after filling in the gaps,[9] and then the aggregated production figures were inflated to 100 percent of non-U.S. world wheat. The source data are shown in Tables 2.5 and 2.6. As a convenient shorthand we will refer to the aggregated forecasts from the ten non-U.S. wheat-producing countries as the "Rest of the World" in the discussions which follow. Appendix A contains the forecast data by individual country from which Table 2.6 was compiled.

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8 U.S.A., U.S.S.R., Canada, Argentina, India, Spain, France, Italy, U.K., Australia and South Africa.

9 By the method described in Section 2.3.

Table 2.5 Monthly and Final Reports of Annual Production of All Wheat Published by the USDA, and Planted Acreage. 1959-1974

Year	Planted Acreage (Millions)	Annual Production (Millions of Bushels)							
		Jun.10	Jul.10	Aug.10	Sep.10	Oct.10	Dec.10	1 Year Later	Jan.1975
1959	56.7	1182	1155	1119	1116	1117	1128	1127	1118
1960	54.9	1211	1347	1362	1368	1368	1363	1357	1355
1961	55.7	1343	1059	1204	1210	1211	1235	1235	1232
1962	49.3	1058	1050	1063	1096	1095	1092	1094	1092
1963	53.4	1084	1111	1151	1234	1133	1137	1142	1147
1964	55.7	1213	1275	1285	1290	1286	1290	1291	1263
1965	57.4	1283	1354	1376	1358	1354	1327	1316	1316
1966	54.1	1235	1240	1286	1296	1296	1311	1312	1305
1967	67.3	1550	1596	1511	1543	1554	1524	1522	1508
1968	61.9	1230	1588	1606	1597	1598	1570	1576	1557
1969	53.5	1161	1425	1459	1457	1456	1459	1460	1443
1970	48.7	1076	1349	1357	1360	1360	1378	1370	1352
1971	53.8	1478*	1548	1601	1625	1628	1640	1618	1618
1972	54.9	1547*	1551	1543	1559	1559	1545	1545	1545
1973	59.0	1745*	1749	1717	1727	1727	1711	1705	1711
1974	71.2	2053*	1925	1894	1792	1781	1793	——	1793

*Publication for all wheat discontinued. This figure is forecast for winter wheat plus first published spring wheat forecast.

Table 2.6 Aggregate "Rest of the World" Wheat Production Forecasts (1960 to 1974)

In Millions of Metric Tons Annually

Year	Month						Final
	MAY	JUNE	JULY	AUG	SEPT	OCT	
1960	178.57	178.57	178.57	178.57	178.57	178.57	
1961	183.57	183.57	183.00	184.86	174.71	172.57	
1962	182.71	182.71	186.29	180.29	202.86	202.14	
1963	192.00	192.00	189.43	192.43	200.71	201.43	
1964	188.86	188.86	188.86	190.71	193.57	193.57	
1965	195.71	195.71	199.14	201.00	208.86	208.29	
1966	193.14	197.14	197.57	199.57	207.86	208.14	
1967	206.43	206.86	212.14	212.14	211.86	214.86	
1968	218.43	218.43	218.43	218.43	228.00	227.14	
1969	235.43	242.57	242.57	242.57	243.00	243.14	
1970	239.43	235.29	235.29	235.29	228.29	227.43	
1971	250.57	250.57	250.57	250.57	259.00	260.00	
1972	252.29	253.43	254.43	253.86	263.86	264.43	
1973	272.14	272.14	275.00	272.29	272.29	269.57	
1974	270.57	270.57	272.57	284.29	285.43	275.43	
	NOV	DEC	JAN	FEB	MAR	APR	
1960	178.57	178.57	177.14	177.14	177.14	178.00	178.86
1961	172.57	172.57	172.57	172.57	172.57	174.71	174.86
1962	202.14	201.86	203.14	203.86	204.71	204.71	207.43
1963	199.43	200.43	202.57	205.71	205.71	205.71	179.29
1964	193.57	190.57	198.71	201.00	201.00	202.43	220.14
1965	208.86	207.00	205.00	204.57	193.71	191.71	194.86
1966	207.71	208.43	210.43	209.57	211.00	263.00	259.71
1967	230.86	231.43	228.00	227.86	227.86	223.00	219.29
1968	231.14	231.14	231.14	230.57	230.57	233.71	261.86
1969	242.86	245.71	245.71	246.00	245.00	245.00	240.00
1970	227.71	243.14	239.57	240.00	239.86	239.86	246.43
1971	260.00	258.86	258.86	257.29	257.29	257.29	[illegible]
1972	264.43	264.86	265.86	270.00	270.00	264.71	257.29
1973	269.57	288.57	288.57	288.86	288.86	288.86	255.86
1974	275.29	275.29	269.00	269.00	269.00	269.00	272.71

Source: Grain Bulletin and FAO

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2.2 The Potential of Remote Sensing Satellite for Improved Crop Surveys

Investigators at the Laboratory for Application of Remote Sensing at Purdue, the Center for Remote Sensing Research at the University of California-Berkeley, the Earth Observations Divison of NASA/Houston, the Space Technology Labs at the University of Kansas, and others have clearly demonstrated the capability to identify major crops and measure their acreage over large areas using LANDSAT imagery. Recently reported results[10] for 10,000 acre test areas in North Dakoata and Saskatchewan show 99 percent of the area under cultivation for grains correctly classified. Better than 91 percent correct classification was achieved in all other land-use categories in these test sites. By using scientific sampling methods, these crop acreage measurements could be extended to the entire crop-growing farmland of a nation or the world, providing that:

- the sample areas can be observed essentially cloud free at the time of overflight;
- the classification of agricultural land use in the sample areas can be calibrated to some known reference fields.

At the present time, neither of these technical problems has been completely solved on a worldwide basis, but if they are solved, there is a clearly demonstrated potential for obtaining accurate estimates of crop acreages by satellite remote sensing.

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[10] D.D. Egbert, D.L. Dietrich and R.E. Fries, "Agricultural Analysis of LANDSAT Digital Data From Williams County, North Dakota, Using G.E. Image 100 System," NASA Earth Resources Survey Symposium, Houston, June 1975.

The level of accuracy of these estimates applied to national crop acreages cannot yet be predicted. However, the Large Area Crop Inventory Experiment (LACIE) program of three U.S. federal agencies (NASA, USDA and NOAA) is designed to provide a pilot test of this application.

In addition to the potential for improved accuracy of crop information, remote sensing satellites also promise to supply more timely information. Currently the crop production (harvest) figures published by F.A.O. are available for some countries only at harvest time or even later. On the other hand USDA publishes forecasts for the U.S. annual wheat crop starting in June, and continuing every month until the harvest is completed. The remote sensing satellite system appears to offer a practical way for extending this pre-harvest forecasting capability to other countries at an acceptable cost. The early information on acreage of growing crops in foreign countries may potentially be even more significant than the improved accuracy.

Design of a good sampling plan, one which can maintain statistical reliability in spite of cloud cover or other interference with data acquistion from the crop-growing farmland areas, is an unsolved but not especially difficult problem. The present-day costs of data collection and processing necessitate a sampling plan which budgets the area coverage carefully. Future costs may be so low that a complete census of all agricultural cropland becomes feasible, but this is not foreseeable

today. In sampling cropland areas in foreign countries, it is possible that the governments of those countries will resist the satellite overflights, but unlikely, based on experience to date. More likely, the need to calibrate crop classifications from satellite imagery with known reference fields in each sample area will cause some intergovernmental problems. In relation to this issue, technological advances will open some doors, and for the rest, we must assume that cooperative solutions will be obtained where necessary for the success of the system, since all the countries involved in production or consumption of a crop stand to gain from its application.

2.2.1 Crop Acreage Measurement from Remote Sensing Imagery

The crop acreage for a particular agricultural region may be loosely defined as the number of acres which have been planted for cultivation of the crop, and in which conditions are favorable to the growth of that crop. As the season advances from planting toward harvest, the harvestable acreage changes - gradually due to changing weather, soil and moisture conditions in the region - drastically due to infrequent catastrophes, such as major floods, which destroy large amounts of crops. The measurement of crop acreage for the purpose of making crop production forecasts must ideally be done close to harvest to avoid errors which would result from inclusion of acreage which was planted but is not harvestable. In practice, the process of measurement is one of continual update of the acreage "to be harvested," beginning soon after planting and

continuing until the crop harvest is complete within the region of the survey.

There is a certain amount of ambiguity in the definition of crop acreage as used in the estimates of crop production prepared by responsible agencies such as the USDA's Statistical Reporting Service or the U.N.'s Food and Agriculture Organization. This problem will be compounded when new remote sensing estimation techniques for crop acreage are introduced.

In order to provide a meaningful analysis of the errors of measurment for crop acreages it will be important to use as a baseline, wherever possible, the concept of an ideal measurement: the true acreage at harvest, which of course cannot be known perfectly. Nevertheless it serves as a reference point for all other definitions of crop acreage.

Remote sensing imagery can be successfully applied to the measurement of crop acreage providing:

- the fields of that crop can be identified within the images (and are not obscured by clouds)
- th area of the fields on the images can be geometrically calibrated
- the boundaries of the fields can be resolved to sufficient accuracy.

The multispectral scanners imagery as well as some of the high resolution photographic imagery available for large agricultural regions meet these conditions to some extent.

2.2.2 Accuracy of Agricultural Crop Measurements Derived From Remote Sensing Imagery

The remote sensing of crop acreage can be performed

at almost any desired level of accuracy if cost is not considered. To achieve a cost-effective operational system for measuring worldwide crop acreage, one must assume a satellite with sensors that have well defined capabilities; in particular, the identification of the crops from the imagery is a key requirement. With that in mind, we will discuss the accuracy with reference to satellite-borne sensors similar to the multispectral scanner on LANDSAT.

The crop production forecasts are the result of a process of data collection, evaluation and integration which is illustrated in Figure 2.1. The errors in the final forecast are a composite of errors of sampling, measurement and inference. In order to know the accuracy (by error analysis) of the forecast, one needs to know the accuracy of all the components.

Algebraic analysis of the formula

Production = Acreage X Yield Per Acre

i.e., $P = AY$

shows that the relative errors for acreage and yield are additive.

$$\frac{\Delta P}{P} = \frac{\Delta A}{A} + \frac{\Delta Y}{Y}$$

This simple fact does not take into account the propagation of errors through the forecasting model. However, the forecasting contribution to error can be associated exclusively with the yield component so that the acreage component can be treated as a current estimate. Since the remote sensing in-

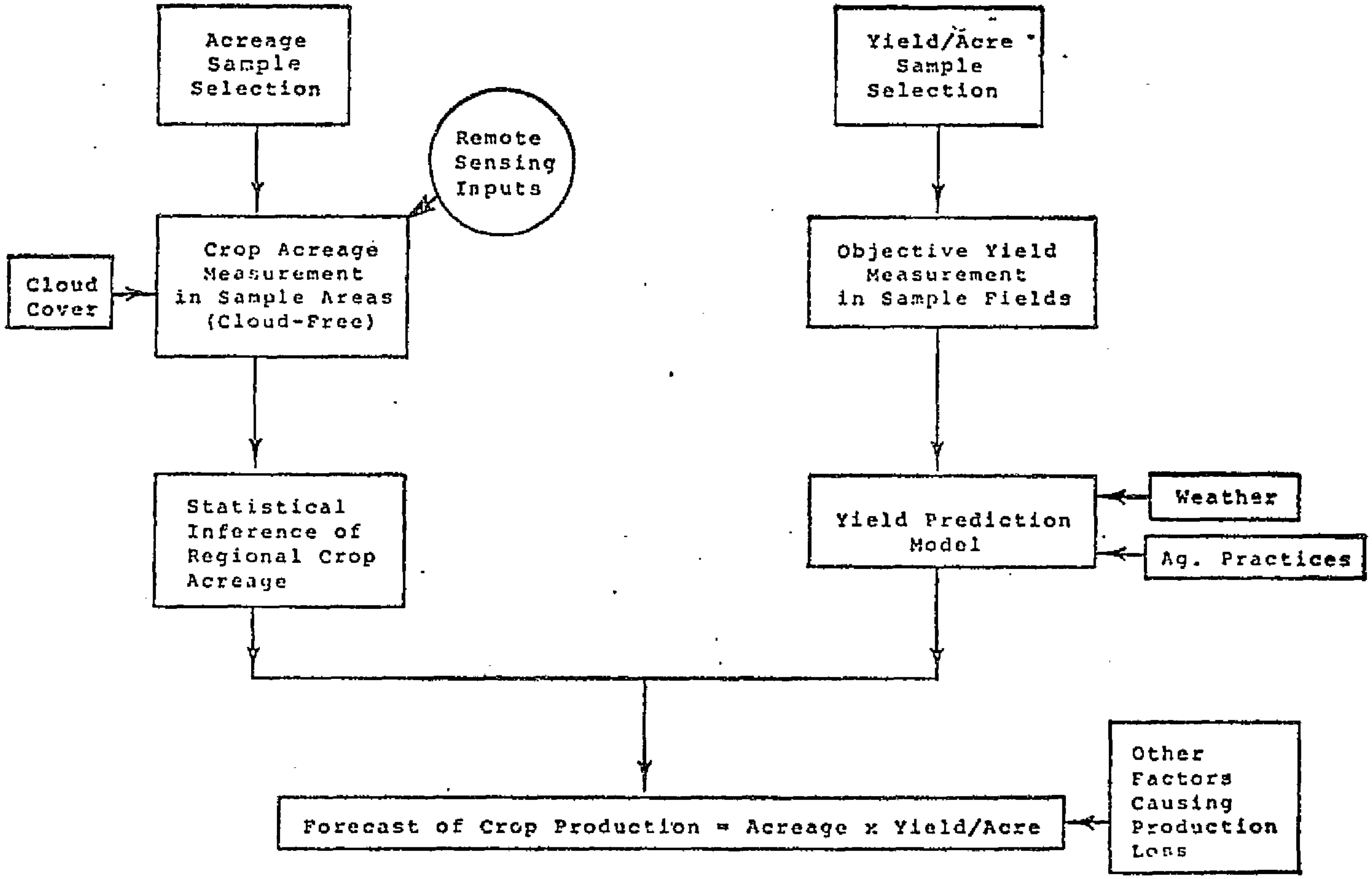

Figure 2.1 Illustrative Flowchart for Crop Forecasts

puts are only on the acreage side at present, we will explain the errors in terms of

- an unimproved part, the yield component, which is assumed not to be affected by remote sensing using LANDSAT for purposes of this assessment;
- an improved part, the acreage component, which is affected by remote sensing using LANDSAT.

This assumption will result in conservative lower bounds for the improvement of accuracy of crop production forecasts, and any improvements of the yield component which develop will independently increase the overall accuracy.

The major sources of error in the crop acreage estimates at harvest are measurement error and sampling error, as discussed in Section 2.1. In evaluating a new technology (such as LANDSAT) for obtaining crop acreage measurement, a trade-off between the sampling errors and measurement errors arises. The existing technology gives estimates with higher measurement accuracy but much lower sampling fraction than the new technology (for instance). The total error is, of course, the only one that really matters. However, improvements may be achieved in either of the two dimensions of the error separately. See Figure 2.2 for a schematic presentation of these ideas.

These comparisons of crop acreage estimates from different sources are even more applicable to worldwide agricultural crop forecasting. The scientific sampling of crops in many other wheat-producing countries is at a far lower level than in the U.S. and Canada, if it exists at all. Hence the achievement of a global crop survey capability with LANDSAT

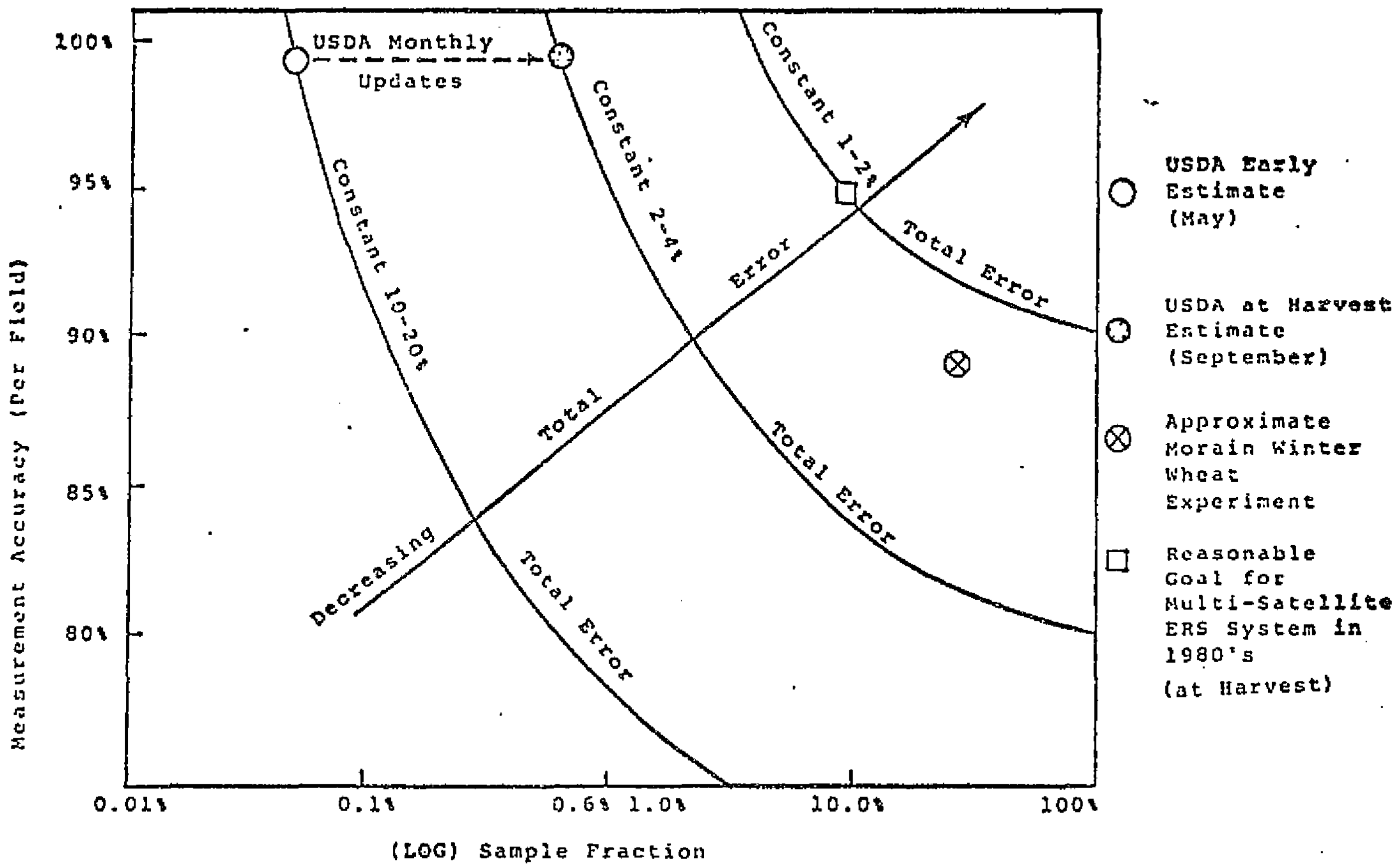

Figure 2.2 Schematic constant Total Error Curves (annual crop estimates) -- Wheat, U.S. National Crop

for wheat, based on a scientifically designed sample, will bring a significant reduction in total error. This remains true even if the measurement of individual wheat fields in the sample is only moderately accurate as long as a consistent measurement bias can be avoided.

In the published forecasts of harvest by the world's largest grain producer, the USSR, there are apparently enormous errors or falsehoods; witness the "surprisingly" large shortfalls in 1972 and again in 1975. In cases like this, there is a need for more objective crop reporting and the remote sensing satellite, whatever other errors it may lead to in crop reports does provide a source of objective measurements.

2.2.3 The Accuracy of LANDSAT Crop Area Mensuration As a Function of Field Size and Spatial Resolution

Table 2.7 records a scatter of reported acreage mensuration results by NASA principal investigators. Without enhancement by secondary processing using "ground truth" data, these range from 45 percent to 84 percent; after processing they range from 95 percent to 98 percent. The lower accuracies are a result of poor identification; using aerial photography and SRS data the identification is significantly improved leaving nearly pure mensuration error. The mensuration error for crop acreage, isolated from identification error and other sources of error, has been characterized in the NASA's Task

Table 2.7 Remote Sensing Accuracy of Area Mensuration: ERTS-1

Source	Prime Subject	Average Field Size (acres)	Percent Correct Classification of Fields	
			Before Secondary Processing	Before Secondary Processing
Thomson - ERIM	rice	174	84%	98%
Malila and Nalepka - ERIM	lakes	18	45%	96%
Morain - U.Kansas	wheat	96	-	95%
Von Steen - USDA	soybeans and cotton	20	72 - 80%	98%

Source: D. B. Wood, "The Use of The Earth Resources Technology Satellite (ERTS) For Crop Production Forecasts," Draft final report by Task Force on Agricultural Forecasting, July 1974.

Force Report[11] by the relationship

$$e = \pm 2K \sqrt{\frac{a}{A}}$$

where e = relative error of pure mensuration

a = pixel area (approx. 1.1 acres)

A = field size in acres

K = adjustment factor for secondary processing.

This approach can be improved by considering the problem in statistical terms. The errors of remote sensing measurement for crop acreage derive mostly from the misclassification of area units or pixels. There are two types of misclassifiaction error in relation to the measurement of acreage for a specific crop such as wheat: (i) failure to identify wheat areas as wheat (nonrecognition), and (ii) the identification of a nonwheat area as a wheat area (false alarm). A binomial probability model[12] for the statistical errors in remote sensing mensuration of an area A gives the following results for the first two moments of the distribution of relative error:

$$E(e) = \frac{sr}{2\sqrt{A}} (p_2 - p_1)$$

$$V(e) = \frac{sr^3}{A^{3/2}} (p_2 q_2 + p_1 q_1)$$

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[11] D. B. Wood, "The Use of the Earth Resources Technology Satellite (ERTS) for Crop Production Forecasts," Draft final report by Task Force on Agricultural Forecasting, July 1974.

[12] See Appendix C.

where e = the error of mensuration relative to a

s = shape factor = 4 for square field

r = length of the side of 1 pixel

p_1 = probability of nonrecognition of wheat

p_2 = probability of false alarm for wheat

$q_1 = 1 - p_1$, $q_2 = 1 = p_2$.

From these it is possible to calculate an approximate 95 percent confidence interval for the relative errors:

$$(E(e) - (1.96)\sqrt{V(e)} \text{ , } E(e) + (1.96) \sqrt{V(e)} \text{)}$$

Table 2.8 provides a sensitivity analysis for the relative errors based on this confidence interval formulation. It is important to realize that, even when $p_2 = p_1$ and the expected relative error is zero (no bias in classification of wheat), there is still a substantial possibility of significant error due to the nonzero variance. With both p_1 and p_2 at 10 percent for example, the 2-sigma limits for relative error are at 5.3 percent, allowing for even greater relative error than 5.3 percent once out of twenty times.

The results of this analysis are not conclusive for crop production forecasts, since they do not take into account the variability of yield per acre, nor do they account for the propagation of error through the time-dependent aspects of the forecasting system. In our modeling approach, to be described in Section 2.3, we will adopt another point of view with regard

Table 2.8 Sensitivity Analysis of Relative Error of Area Mensuration for 100-pixel Scenes with Varying Non-Recognition and False Alarm Error Rates						
p_1 = Probability of Non-recognition; p_2 = False Alarm Rate. Parenthetical Figures Are 95% Confidence Limits; Beneath Them Are Expected Values of Relative Error %						
p_1 \ p_2	0.00	0.01	0.05	0.10	0.25	0.50
0.00	(0,0) 0	(-1.0, 1.4) 0.2	(-1.7, 3.7) 1.0	(-1.7, 5.7) 2.0	(-0.4, 10.4) 5.0	(3.8, 16.2) 10.0
0.01	(-1.4, 1.0) -0.2	(-1.7, 1.7) 0	(-2.2, 3.8) 0.8	(-2.1, 5.7) 1.8	(-0.7, 10.3) 4.8	(3.5, 16.1) 9.8
0.05	(-3.7, 1.7) -1.0	(-3.8, 2.2) -0.8	(-3.8, 3.8) 0	(-3.6, 5.6) 1.0	(-2.0, 10.0) 4.0	(-2.2, 15.8) 9.0
0.10	(-5.7, 2.1) -2.0	(-5.7, 2.1) -1.8	(-5.6, 3.6) -1.0	(-5.3, 5.3) 0	(-3.5, 9.5) 3.0	(0.9, 15.2) 8.0
0.25	(-10.4, 0.4) -5.0	(-10.3, 0.7) -4.8	(-10.0, 2.0) -4.0	(-9.5, 3.5) -3.0	(-7.6, 7.6) 0	(-3.2, 13.2) 5.0
0.50	(-16.2, -3.8) -10.0	(-16.1,-3.5) -9.8	(-15.8, -2.2) -9.0	(15.2, -0.8) -8.0	(13.2, 3.2) -5.0	(-8.8, 8.8) 0

to the errors in crop production forecasting, which is more suited to the requirements of the benefits analysis. The discussion so far has provided a background of plausibility for improved crop forecasting using a remote sensing satellite system, since it is always feasible to combine improved acreage information with current knowledge of yields per acre. The development of a worldwide remote sensing crop survey would supply timely and comprehensive information on growing crop acreages, resulting in both increased objectivity and increased sample coverage of the total cropland.

2.3 "Information System": Current Version

As described in Section 2.1, the 1960-1974 USDA Crop Production, U.K. Grain Bulletin and FAO Production Yearbook data on worldwide wheat production were analyzed for assessment of the forecast errors in the current "information system." The modeling approach of the present section requires as inputs estimates of the variances of the annual wheat production forecast, published monthly, for the United States and the Rest of the World. In addition, the variance of the final production estimate for each crop year is required.

Information on the size of the new crop of wheat each year is generally available in Spring.[13] We have chosen to start the crop year on June 1 to synchronize the model of

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[13] USDA published its first forecast of winter wheat production for the U.S. in April until 1971, and in May since then and the first forecast of all wheat in June.

the information system with observed fact. The Grain Bulletin supplies forecasts of expected future and present wheat production in most of the eleven countries on our select list in its September issue each year. Thus to obtain earlier forecasts for non-U.S. countries -- June through August -- it was sometimes necessary to construct five-year moving averages of wheat production in previous years as described in Section 2.1. Although the Southern hemisphere countries--Argentina, Australia, and South America--are six months out of phase with the Northern countries, the information available on their November-January winter wheat harvest does not appear early enough in the published sources to make a significant difference to our modeling approach.

Table 2.9 shows the completed series of all wheat production forecasts for the U.S. in 1960-1974: in months for which new forecasts are published by USDA, these are converted to millions of metric tons and used;[14] all other figures are either continuations of the previous monthly forecasts or in case of the early months, five-year moving averages of final USDA production estimates. The "final" column contains the final USDA production estimate of all wheat production, which is published at the end of the year following the harvest. These figures were obtained, unlike those for other countries, from the USDA Crop Production.

[14] USDA has generally expressed production forecasts in millions of bushels.

Table 2.9 Forecasts of United States All Wheat Production in 1960-1974 and Final Estimates of Same (millions of metric tons).

YEAR	JUNE	JULY	AUG	SEPT	OCT	NOV
1960	33.0	36.7	37.1	37.2	37.2	37.2
1961	36.6	28.8	32.8	32.9	33.0	33.0
1962	28.8	28.6	28.9	29.8	29.8	29.8
1963	29.5	30.2	31.3	33.6	30.8	30.8
1964	33.0	34.7	35.0	35.1	35.9	35.0
1965	34.9	35.9	37.5	37.0	36.9	36.9
1966	33.6	33.8	35.0	35.3	35.3	35.3
1967	42.2	43.4	41.1	42.0	42.3	42.3
1968	33.5	43.2	43.7	43.5	43.5	43.5
1969	31.6	38.8	39.7	39.7	39.6	39.6
1970	29.3	36.7	36.9	37.0	37.0	37.0
1971	40.2	42.1	43.6	44.2	44.3	44.3
1972	42.1	42.2	42.0	42.4	42.4	42.4
1973	47.5	47.6	46.7	47.0	47.0	47.0
1974	55.9	52.4	51.6	48.8	48.5	48.5

YEAR	DEC	JAN	FEB	MAR	APR	FINAL
1960	37.1	37.1	37.1	37.1	37.1	36.9
1961	33.6	33.6	33.6	33.6	33.6	33.5
1962	29.7	29.7	29.7	29.7	29.7	29.7
1963	30.9	30.9	30.9	30.9	30.9	31.2
1964	35.1	35.1	35.1	35.1	35.1	34.9
1965	35.1	36.1	36.1	36.1	36.1	35.8
1966	35.7	35.7	35.7	35.7	35.7	35.5
1967	41.5	41.5	41.5	41.5	41.5	41.0
1968	42.7	42.7	42.7	42.7	42.7	42.4
1969	39.7	39.7	39.7	39.7	39.7	39.3
1970	37.5	37.5	37.5	37.5	37.5	36.8
1971	44.6	44.6	44.6	44.6	44.6	44.0
1972	42.1	42.1	42.1	42.1	42.1	42.1
1973	46.6	46.6	46.6	46.6	46.6	46.6
1974	48.8	48.8	48.8	48.8	48.8	48.8

Source: USDA Crop Production.

Interpolation by ECON.

Table 2.10 shows the completed series of all wheat production forecasts for the aggregated Rest of the World, i.e., all wheat-producing countries other than the United States. The method for constructing the series was the same as for the United States, except that two additional steps were necessary:

- aggregation of total wheat production for the ten non-U.S. countries on the select list

- inflation to 100 percent through division by 0.70 since these countries represented approximately 70 percent of the total non-U.S. wheat production.

From these data the forecast variances are calculated. The sample years, 1960-1974, represent a period in which the production of wheat increased markedly: about 36 percent for the United States, 47 percent for the Rest of the World. It is possible that, as the harvest size increases, the absolute forecast will increase through the sample years, representing perhaps a constant relative (percent) error. If so, the estimates of relative error will be somewhat better than the estimates of absolute error, and vice versa if there is a tendency towards constant absolute error. To explore these possibilities we performed a simple linear detrending of the forecast errors and recalculated the variances. The results show that there is no significant trend in the absolute forecast errors for the years 1960 to 1974 for the United States wheat production, but that for the Rest of the World there is a slight downward trend in absolute forecast error over the fifteen sample years for cer-

Table 2.10 Forecasts of the Rest of the World All Wheat Production in 1960-1974 and Final Estimates of Same (millions of metric tons).

YEAR	JUNE	JULY	AUG	SEPT	OCT	NOV
1960	178.8	178.8	178.8	178.8	178.8	178.8
1961	183.0	183.2	185.0	174.9	172.7	172.7
1962	182.9	188.5	188.5	203.1	202.3	202.3
1963	192.2	189.6	192.6	200.9	201.6	199.6
1964	183.0	189.0	190.9	193.8	193.8	193.8
1965	195.9	199.3	201.2	209.1	208.5	209.1
1966	197.3	197.8	199.8	208.1	208.4	207.9
1967	207.1	212.4	212.4	212.1	215.1	231.1
1968	218.6	218.6	218.6	228.2	227.4	231.4
1969	242.8	242.8	242.8	243.2	243.4	243.1
1970	235.5	235.5	235.5	228.5	227.7	227.9
1971	250.8	250.8	250.8	259.3	260.3	260.3
1972	253.7	254.7	254.1	264.1	264.7	264.7
1973	272.4	275.3	272.6	272.6	269.8	269.8
1974	270.8	272.8	284.6	285.7	275.7	275.6

YEAR	DEC	JAN	FEB	MAR	APR	FINAL
1960	178.8	177.3	177.3	177.3	178.2	179.0
1961	172.7	172.7	172.7	172.7	174.9	175.0
1962	202.1	203.3	204.1	204.9	204.9	207.6
1963	200.6	202.8	205.9	205.9	205.9	179.5
1964	193.8	196.9	201.2	201.2	202.6	220.4
1965	207.2	205.2	204.8	193.9	191.9	195.1
1966	208.6	210.6	209.8	211.2	263.3	260.0
1967	231.7	228.2	228.1	228.1	228.2	219.5
1968	231.4	231.4	230.8	230.8	233.9	262.1
1969	246.0	246.0	246.2	245.2	245.2	240.2
1970	243.4	239.8	240.2	240.1	240.1	248.7
1971	259.1	259.1	257.5	257.5	257.5	269.8
1972	265.1	266.1	270.3	270.3	265.0	257.5
1973	288.9	288.9	289.1	289.1	289.1	296.2
1974	275.6	269.3	269.3	269.3	269.3	273.0

Source: U.K. Grain Bulletin and FAO Production Yearbook. Interpolation and Extrapolation by ECON.

tain months. There is also a slight negative bias in the R.O.W. forecasts. These effects, while interesting in themselves, have no further bearing on the present study. Full discussion and analysis of this issue is available in ECON's working papers. Table 2.11 shows the estimated variances.

In months such as November and January through April no significant new information was presented for the United States and the forecast variance does not change in these months. Large forecast errors in March and April for the Rest of the World represent drastic revisions in some years of the late estimates of the completed harvest. The two sets of forecast variances characterize the current information system for the model and represent the baseline inputs. In the next section, we will discuss the method of estimation for the "improved" variances and compare the results with Table 2.11.

2.4 Information System: Operational LANDSAT With LACIE Goals

The statistical properties of a future system which does not yet exist in an operational form are necessarily somewhat speculative. The accuracy with which wheat acreage in the United States can be identified and measured using LANDSAT digital data is known to some extent from scientific research over the past three to four years. But this does not yet allow precise inferences regarding the statistics of crop production forecasting from a hypothetical LANDSAT operational system. The extent of uncertainty due to weather and crop stress, the effects

Table 2.11 Estimated Forecast Error RMS by Month Within Crop Year: 1960-1974

Month	U.S.A. i	U.S.A. MMT	U.S.A. % of Actual	R.O.W. i	R.O.W. MMT	R.O.W. % of Actual
May	1	3.3892	8.7866	1	16.502	7.113
June	2	3.1295	8.1134	2	17.985	7.752
July	3	1.3047	3.3826	3	18.356	7.912
August	4	0.7661	1.9862	4	18.889	8.142
September	5	0.7313	1.8959	5	16.272	7.014
October	6	0.5234	1.3570	6	15.855	6.834
November	7	0.5234	1.3570	7	16.665	7.183
December	8	0.2633	0.6827	8	15.820	6.819
January	9	0.2633	0.6827	9	14.282	6.156
February	10	0.2633	0.6827	10	15.836	6.826
March	11	0.2633	0.6827	11	15.734	6.782
April	12	0.2633	0.6827	12	15.769	6.797

Source: ECON calculation based on Tables 2.5 and 2.6

of data losses and delays, the integration of LANDSAT data with other agricultural data to form a new forecast -- all of these effects exist and remain relatively unquantified. Consequently, we must model the information system in a different way to arrive at a set of crop production forecast variances which are the required inputs to the benefits model.

The approach to be followed in the present section will derive its methodology from the probability theorem of A. Kolmogorov[15] and its standards of achievement from the early LACIE goals: 90 percent accuracy, with 90 percent confidence. Without needing to assume a parametric form for the distribution of future wheat production forecasts from a LANDSAT system, we will use Kolmogorov's Inequality Theorem to derive a measure of relative forecast accuracy from the "90-90" goal. The theorem states:

> Let $X_1, \ldots, X_n$ be mutually independent variables with expectations $\mu_k = E(X_k)$ and variances σ_k^2. Put
>
> $$S_k = X_1 + \ldots + X_k \tag{2.4.1}$$
>
> and
>
> $$m_k = E(S_k) = \mu_1 + \ldots + \mu_k \text{ ,} \tag{2.4.2}$$
>
> $$s_k^2 = \mathrm{Var}(S_k) = \sigma_1^2 + \ldots + \sigma_k^2 \text{ .} \tag{2.4.3}$$

---

[15] See Section 9.7 of: "Probability Theory and its Applications," Volume 1., by W. Feller, Wiley, 1950.

For every $t>0$, the probability of the simult-taneous realization of the n inequalities:

$$|s_k - m_k| < ts_n \ , \ k = 1, 2, \ldots, n \qquad (2.4.4)$$

is at least $1 - t^{-2}$.

The information system will generate, within each crop year, a sequence of production forecasts and estimates (depending on the time of publication in relation to harvest):

$$F_1 \ , \ F_2 \ , \ \ldots \ , \ F_k \quad \text{where } k \leq 12$$

which may be indexed $i = 1, 2, \ldots, 12$, as in Table 2.11 from May through April. One more estimate F_{13}, represents the final revision of the crop production for that crop year and may be published much later. However, we assume that this final estimate represents "the truth" and that the market is essentially aware of its value before the new crop information commences in the second May. Now let

$$X_i = F_{13-(i-1)} - F_{13-i} \text{ for } i = 1,2,3,\ldots,12. \qquad (2.4.5)$$

We assume that the forecasts are <u>unbiased</u>, so that

$$E(F_i) = F_{13} \text{ and } E(X_i) = \mu_i = 0$$
$$\text{for } i = 1,2,\ldots,12 \ . \qquad (2.4.6)$$

and that the X_i are mutually independent and have constant[16] variance σ^2. Applying the theorem to the X's now gives the following useful result:

Prob (For k = 1, 2, ... , 12:

$$\left|\sum_{i-1}^{k} X_i\right| = |F_{13} - F_k| \leq 10.95450) \geq .90 \qquad (2.4.7)$$

by choosing $t^2 = 10$ and $n = 12$ in (2.4.4), since $s_n = (n\sigma^2)^{\frac{1}{2}}$ and $(nt^2)^{\frac{1}{2}} = 10.9545$. The statement can be interpreted as a simultaneous 90 percent confidence intervals for the forecast errors through the crop year.

The achievement of 90 percent accuracy by the forecasts F_k means that $|F_{13} - F_k| \leq .10\ F_{13}$. To satisfy the inequality (2.4.7) for all k= 1,2,3,...,12, we must have:

$$10.95450 = 0.10F_{13} \qquad (2.4.8)$$

While the value 0.9 percent of "true" production seems to very small for σ, it should be remembered that this relates to the difference between consecutive monthly forecasts in our model. The actual forecast variances are $Var(S_k)$ as shown in Table 2.12. The model implies two percent accuracy for the December forecast (estimate) of crop production, which is already achieved in the United States by the current USDA "information system".

A further step is necessary to provide the forecast variances in absolute terms (metric tons) as required for input

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[16] In (2.4.3), this assumption implies $s_k^2 = k\sigma^2$ for $k = 1,2, \ldots , n$.

Table 2.12 Model Forecast Variances as a Fraction of "True" Crop Production

k	Year	Month	$\sqrt{Var(S_k)}/F_{13}$	k	Year	Month	$\sqrt{Var(S_k)}/F_{13}$
1	Y + 1	April	0.00913	7	Y	October	0.0242
2	Y + 1	March	0.0129	8	Y	September	0.0258
3	Y + 1	February	0.0158	9	Y	August	0.0274
4	Y + 1	January	0.0183	10	Y	July	0.0289
5	Y	December	0.0204	11	Y	June	0.0303
6	Y	November	0.0224	12	Y	May	0.0316

Source: ECON calculations and theory.

to the benefits model. These can be modeled in a number of different ways. We chose to simulate the fifteen years of wheat production forecasting using the actual harvest figures (F_{13}) and the theoretical variances of forecast error, $s_k^2 = k\sigma^2 = k(0.009F_{13})^2$ for k=1,2, ..., 12. The major advantage of the simulation is that it permits us to take into account the historical forecasts and to incorporate them into the model whenever they are better than constructed forecasts. In so doing, we are simulating the way in which the market will react to new technological sources of crop information: accepting when it is better than current information, rejecting it otherwise.

Simulating the 180 crop production forecasts (12 each in years 1960 to 1974) with no bias — zero expected value of error — and known σ imposes on us the necessity of choosing a parametric form of probability distribution. While the Gaussian or Normal is a natural choice for error distributions, it has the potentially undesirable feature of "allowing" negative forecast values. In actual practice this may never occur since, with an expected value of the forecast = "true" production = 40 MMT and $s_k = \sqrt{K}\,(.009)\ (40) \leq 1.247$ MMT, the probability of a negative value occurring in 180 randomly chosen numbers is extremely small. So, without fear of implausible values being generated, we will use a Gaussian distribution for the simulated forecasts with mean = "true" production in the crop years and variance, $s_k^2 = k \times (0.009)^2 \times$ ("true" production)^2. Each simulated forecast generated by the

Gaussian random numbers is compared with the historical forecast; whenever the error is smaller in the historical forecast it is substituted for the generated one. Table 2.13 shows the simulation results for United States and the Rest of the World.

Table 2.13 Simulated Wheat Production Forecasts for 1960-1974 Using LACIE 90-90 Target.

Simulated Forecasts for the United States

YEAR	JUNE	JULY	AUG	SEPT	OCT	NOV
1960	34.6	36.7	37.1	37.2	37.2	37.0
1961	32.9	33.9	33.4	33.4	33.0	33.0
1962	28.8	30.3	29.3	29.7	29.8	29.8
1963	31.7	30.2	31.3	31.4	30.8	31.1
1964	35.3	34.7	35.0	35.1	35.0	35.0
1965	34.9	34.8	37.5	35.8	35.7	35.4
1966	34.5	36.5	35.2	35.3	35.5	35.3
1967	41.2	40.9	41.1	40.2	41.4	42.0
1968	43.5	43.2	43.7	42.8	42.2	42.3
1969	39.7	39.8	38.9	39.2	39.6	39.5
1970	36.2	36.7	36.9	37.0	37.0	37.0
1971	41.6	42.5	43.6	44.2	44.3	44.3
1972	42.1	42.2	42.0	41.9	42.4	42.1
1973	46.9	46.9	46.7	47.0	47.0	47.0
1974	48.7	49.5	49.7	48.8	48.5	48.7

YEAR	DEC	JAN	FEB	MAR	APR	FINAL
1960	37.1	37.1	37.1	37.1	36.9	36.9
1961	33.6	33.6	33.6	33.6	33.6	33.5
1962	29.7	29.7	29.7	29.7	29.7	29.7
1963	30.9	31.1	30.9	30.9	30.9	31.2
1964	35.1	35.1	35.1	35.1	35.1	34.9
1965	36.1	36.1	36.1	35.5	36.1	35.8
1966	35.5	35.7	35.7	35.7	35.7	35.5
1967	40.8	41.5	41.5	41.1	41.1	41.0
1968	42.7	42.7	42.7	42.2	42.7	42.4
1969	39.7	39.7	39.7	39.7	39.3	39.3
1970	37.5	37.5	37.5	37.9	37.5	36.8
1971	44.1	41.6	44.5	44.2	43.7	44.0
1972	42.1	42.1	42.1	42.1	42.1	42.1
1973	46.6	46.6	46.6	46.6	46.6	46.6
1974	48.8	48.8	48.8	48.8	48.8	48.8

Simulated Forecasts for the Rest of the World

YEAR	JUNE	JULY	AUG	SEPT	OCT	NOV
1960	178.8	178.8	178.8	178.8	179.1	178.8
1961	166.4	181.5	172.2	174.9	176.7	172.7
1962	212.5	212.9	209.0	203.1	205.1	205.7
1963	176.9	177.9	180.9	171.9	184.9	183.7
1964	213.4	225.2	219.2	204.4	223.5	227.2
1965	195.9	199.3	201.2	202.1	204.4	191.8
1966	270.2	252.2	264.3	259.6	259.7	254.9
1967	216.1	212.4	214.8	220.6	215.1	214.4
1968	261.3	260.7	258.4	257.3	265.0	260.1
1969	242.8	242.8	238.5	242.2	240.5	243.1
1970	236.6	250.9	239.7	242.6	240.2	245.4
1971	280.8	263.1	274.4	269.7	268.7	260.3
1972	254.8	256.4	256.8	261.4	257.8	264.7
1973	302.5	293.1	293.6	295.3	294.3	297.3
1974	270.8	272.8	276.2	268.5	275.7	275.6

YEAR	DEC	JAN	FEB	MAR	APR	FINAL
1960	178.8	179.1	177.3	177.3	173.2	179.0
1961	174.2	176.0	175.1	174.9	174.9	175.0
1962	202.1	203.9	209.0	204.9	205.0	207.6
1963	176.3	185.7	181.1	181.3	179.6	179.5
1964	224.5	219.1	220.3	220.5	222.9	220.4
1965	194.8	191.0	198.8	193.9	195.5	195.1
1966	266.0	255.9	261.3	263.2	260.1	260.0
1967	213.5	217.1	218.0	216.2	219.7	219.5
1968	259.7	258.6	261.2	256.7	261.0	262.1
1969	240.5	240.9	242.5	235.4	240.4	242.2
1970	245.5	255.5	247.9	252.4	249.9	241.7
1971	277.2	264.3	265.5	270.5	266.4	265.6
1972	253.6	254.1	256.4	258.3	255.2	257.5
1973	288.9	289.7	297.7	290.7	297.5	296.2
1974	275.6	269.3	269.3	273.9	274.8	273.0

3. A MODEL OF THE WORLD MARKETS FOR WHEAT

"The specific method of economics is the method of imaginary construction"[17]

3.1 Introduction

The structures describing the world markets for wheat first are presented in general terms. Here, our focus is on the behavioral formulations and general characteristics of the model. Particular structures for the equations and estimation results then are presented.

Before describing the model, an important convention must be noted. The structures describing the behavior of the various "players" are stated directly and are not derived from presupposed utility and profit function. That is to say, rather than postulate "utility" functions from which a utility maximizing demand curve can be derived, the demand relationships are postulated directly. Similarly, the supply side consists of relationships that reflect profit maximizing behavior on the part of suppliers.

The model is presented in four parts. The first part, (Section 3.2) describes the demand block for the typical spot market in a region. Included here are the demand for human consumption, animal feed, seed, exports and inventories. Section 3.3. summarizes the supply side of the typical spot market. The relationships for production, harvested acres and yield are presented here. The demand for, and supply of, futures contracts

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[17] Von Mises [124], page 236.

is presented next. Unlike the spot markets, only one futures market serves "the world." Finally, an overview of the complete model is presented in Section 3.6.

3.2 The Demand Block for the Typical Spot Market

Following the tenets of economic theory, the current (spot) demand for a good or service at any point in time (t) is assumed to be a function, in part, of its own price, the prices of substitutes and complements, and selected other influeneces determined outside the model, "exogenous variables," such as income and population. Denoting current prices P_t and the "other" variables by the vector, X_t, the demand relationship for wheat in the spot market at time t, D_t can be written

$$D_t = D(P_t, X_t) + U_t \tag{3.1}$$

where U_t is a random "residual" reflecting some combination of the random element in human behavior and the combined effect of omitted variables.

For wheat, as with many other agricultural commodities, "the demand for wheat" is in fact made up of five different demands for wheat: human consumption (food), animal feed, seed, inventory and net exports. Each is described further below.

3.2.1 Human, Animal Feed and Seed "Disappearance"

Excluding inventory demand and exports (for now), wheat demand has three parts: demand for human consumption, C_t, (food), demand for seed, F_t, and demand for animal feed,

F_t. Although each of these demands may be expressed in the same general form, specified in (3.1) above, the arguments for each type of demand contain many unique elements. For example, animal population and cattle prices are not likely to enter the demand structure for human wheat consumption, at least not directly. To be sure, these factors may enter indirectly through various market channels and may be revealed explicitly in more general and inclusive "reduced form" relationships. However, we present here "structural" equations and not "reduced form" ones in order to be able to trace the impacts of information improvement through the economy and identify the benefits to specific market participants.

Moreover, the different demands may exhibit different degrees of price responsiveness. Thus, the total domestic demand for wheat (excluding inventory demand), may be viewed as three distinct but similar demands for wheat.

3.2.2 Inventory Demand

The domestic stock of wheat, which gives rise to the fourth demand for wheat, introduces stock adjustment dynamics into the demand side of our model.[18] The domestic private stock of wheat I_t, is assumed to be a function of spot prices P_t, discounted futures prices $P_{t,\tau}$ adjusted for marginal storage and decay costs $\bar{P}_{t,\tau}$ and last period's level in inventory.

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[18] Alternatively, inventory may be treated as a component of supply.

This function is denoted

$$I_t = \gamma q \left[\bar{P}_{t,\tau} - P_{t,\tau}\right] + (1 - \gamma)\ I_{t-1} + U_{2t} \qquad (3.2)$$

$$I_t \geq I_0 \geq 0.$$

where I_0 is the level of "buffer inventories," and $\bar{P}_{t,\tau}$ is the discounted and adjusted futures price and U_{2t} is a random error.

The discounted and adjusted futures price is

$$\bar{P}_{t,\tau} = \frac{(1-\delta)^{\tau}}{(1+r)^{\tau}} \ P_{t,\tau} - C\tau, \qquad (3.3)$$

where δ is the decay rate, r is the discount rate, C is the marginal cost of storage, and τ is the lead time of the futures price.

Substituting (3.3) into (3.2) we get

$$I_t = \gamma q \left(\left[\frac{(1-\delta)}{(1+r)}\right]^{\tau} P_{t,\tau} - C - P_t\right) + (1-\gamma) I_{t-1} + U_{2t} \qquad (3.4)$$

$$I_t \geq I_0 \geq 0 .$$

It must be noted that the buffer stock I_0, when encountered, will lead to asymmetric economic behavior that, in turn, will lead to asymmetric welfare effects.

Finally, it also should be noted that the total stock of a commodity in a country, I_t, consists of the sum of private stocks PI_t plus government stocks GI_t. That is,

C.2

$$I_t = PI_t + GI_t. \tag{3.5}$$

For our purposes, GI_t is "exogenous" to the model.

3.2.3 Exports

There is, of course, one further demand for wheat and that is the foreign demand for exports. These exports consist of private exports Z_t and government exports G_t. The latter, government exports, are taken as exogenous to the mainstream of the model. The former, however, are endogenous and must be determined. In this study a behavioral export demand equation is not postulated explicitly. Rather, the approach taken here is to determine Z_t from the accounting identity, Total Supply less Total Domestic Demand and less Government Exports equals Private Exports. That is

$$Z_t = G_t - C_t - F_t - S_t - \Delta I_t, \tag{3.6}$$

where $\Delta I_t \equiv I_t - I_{t-1}$.

Summarizing, the demand side of the typical spot market consists of five key relationships:

Export Identity	$Z_t \equiv G_t - C_t - F_t - E_t - \Delta I_t$
Demand for Human Consumption	$C_t = C(P_t , X_t) + U_{Ct}$
Demand for Animal Feed	$F_t = F(P_t , X_t) + U_{Ft}$
Demand for Seed	$E_t = E(P_t , X_t) + U_{Et}$

Inventory Demand

$$I_t = \gamma q \left(\left[\frac{(1-\delta)}{(1+r)}\right]^{\tau} P_{t,\tau} - C\tau - P_t \right) + (1-\gamma)\,(PI_{t-1} + GI_t) + U_{It}$$

$$PI_t \geq I_0 \;.$$

As can be seen, the futures price is an important determinant of demand for wheat as specified in this model. The determinants of the futures price are deferred to Section 3.3 where the futures market is described. The supply side of the spot market is presented next.

3.3 The Supply Block in the Typical Spot Market

In this section, we describe the production of agricultural commodities in a country. Domestic production in country, Q_t, is decomposed into harvested acreage A_t times yield Y_t. In this study yield is determined outside the model.

Following Nerlove [89-91], at least in spirit, the harvested acreage of wheat at time t, A_t, is assumed to follow a "stock adjustment" mechanism. Included here is the desired acreage harvested which is assumed to be a function of the price of wheat, the prices of substitutes and complements and the prices of factors of production, such as fertilizer, etc. However, three sets of these prices may be considered: lagged, anticipated and current actual prices. Lagged and anticipated prices must be considered so as to capture the influence of past returns and expectations on potential or desired harvested acres, i.e., planting intentions. Current prices, relative to past futures prices, may capture the extent to which actual "harvests" depart from the "potential" harvest acreage owing to

unanticipated price developments that make it economically undesirable to harvest all the acres planted. This latter phenomenon is not modeled here and is one of the least significant problems of quantification.

The relationship for desired harvest acreage is denoted by

$$A^*_{t-h} = A\ (P_{t-h},\ P_{t-h,h}) \tag{3.7}$$

where h denotes the time between planting and harvest.

The relationship between actual and desired harvest acreage is of the form

$$A_t = \alpha A^*_{t-h} + (1-\alpha)\ A_{t-12}. \tag{3.8}$$

Combining the above expressions, the semi-reduced relationship describing acres harvested will be of the form

$$A_t = \alpha A(P_{t-h},\ P_{t-h,h}) + (1-\alpha) A_{t-12}. \tag{3.9}$$

Summarizing the supply side of the spot market, we have

Production	Q_t	=	$A_t \cdot Y_t$
Yield	Y_t	=	exogenous
Acres Harvested	A_t	=	$\alpha\ A\ (P_{t-h},\ P_{t-h,h}) + (1 - \alpha) A_{t-12}$

3.4 The Futures Market

Unlike the spot market where separate demand and supply relationships are specified for each country, only one world futures market for wheat is postulated. A multi-market

parallel of the spot market is not justified by the facts.[19] The Chicago market is the dominant world futures market and our model reflects this institutional fact.

However, the futures market, like the spot market, is governed by the forecast of supply and demand and both are described in the following paragraphs.

3.4.1 The Demand For Futures Contracts

The "effective" demand for forward sales contracts is assumed to come from speculators who hope to gain from "backwardation"--the difference between discounted expected spot and future prices. In addition, financial considerations strongly suggest that speculators also may be sensitive to the "variability risk" surrounding their expected gain from backwardation and the cost of money associated with their purchases.

The "variability risk" sensitivity of the demand relationship follows directly from the general character of speculators. In essence, they may be viewed as investors that seek either to maximize the expected return from their investment in commodities subject to a risk constraint or, alternatively, they seek to minimize their risk subject to some earnings requirement. Both of these approaches lead to operating "rules" that equate the speculators demand for futures contracts to "backwardation," the variation in "backwardation" and the cost

[19] Only economic "irrationality" would warrant any different specification.

of money. This demand for forward sales contracts can be written

$$L_{t,\tau} = L\left[(SP_{t,\tau} - P_{t,\tau}, \sigma_B^2, r\right] + U_{Lt} \qquad (3.10)$$

where $SP_{t,\tau}$, is the anticipated spot price, $P_{t,\tau}$ is the futures price, r is the cost of money σ_B^2 denotes the variation in the backwardation component ($SP_{t,\tau}$ $P_{t,\tau}$) and is a natural measure of the risk associated with the expected gains from backwardation, and U_{Lt} is a random element. As can be seen, this relationship requires the determination of futures prices and expected spot prices for a "solution." The mechanisms describing these variables are presented below. Before turning to them, however, we first consider the supply of futures contracts.

3.4.2 The Supply of Futures Contracts

The "effective" supply of forward sales contracts is assumed to come primarily from owners of physical stock-demanding hedges. As in the demand block, the attractiveness of a hedge is assumed to be dependent upon backwardation and its variation. Unlike the demand block, however, total available world stocks of the commodity, I_t, also are assumed to play an influential role.

Algebraically, this supply function can be written

$$H_{t,\tau} = H\left[(SP_{t,\tau} - \bar{P}_{t,\tau}), \sigma_B^2, I_t\right] + U_{H,t} \qquad (3.11)$$

where $U_{H,t}$ is a random residual. As in the demand case for futures contracts, anticipated spot prices and futures prices are necessary for solutions. In the next two sub-sections

these prices are described.

3.4.3 Price Adjustments

As Hicks points out [46], there are "sufficient technical rigidities" in the process of production to make it certain that a number of enterpreneurs will want to hedge their sales. Supplies in the near future are largely governed by the decisions taken in the past, e.g., the amount of acreage sown. The same thing sometimes happens with planned purchases as well, but "it is almost inevitably rare" since technical conditions give the enterpreneur a "much freer hand" in the acquisition of inputs (largely needed to start new production) than in the completion of outputs (whose process of production has already begun). For these reasons, one can expect a "tendency for relative weakness on the demand side" of the futures market. [53, p. 137]

As Labys and Granger point out [70], this reasoning suggests that the short hedging and long speculation represent the <u>"effective" supply of and demand for futures contracts</u>, respectively. In this study we define the difference between the effective supply and demand for futures contracts as <u>effective open interest</u>. Open interest "is the number of futures contracts covered by offsetting contracts or fulfilled by delivery."

In our model, the "natural" imbalance between the forces of demand and supply in the futures market is assumed to influence the rate of change in prices. In particular, it

is assumed that the rate of change in the futures price in the counury that hosts the world futures market, $\Delta P_{t,\tau} \equiv P_{t,\tau} - P_{t-1,\tau}$ is a function of the difference between the "Hicksian" supply and demand for futures contracts. That is

$$\Delta P_{t,\tau} = P[(L_{t,\tau} - H_{t,\tau}] + U_{P,t} \qquad (3.12)$$

where $U_{P,t}$ is a random variable.

At the heart of both the demand and supply side of the futures market is the anticipations mechanism determining $SP_{t,\tau}$. This mechanism, its relationship to crop forecasts and expectations are discussed next.

3.4.4 Anticipated Spot Prices, Crop Forecasts and Expectations

Extending and building upon the empirical insights of others, the market expectations mechanism underlying the anticipated spot price is assumed to be rational in the Box-Jenkins sense [10] and dependent on some combination of futures prices and crop production forecasts. Specifically, the anticipated spot price of a commodity for time t, $SP_{t,\tau}$ is assumed to be determined in part by a distributed lag on future prices

$$\sum_{k=o}^{n} d_{1k} \cdot P_{t-k,\tau} \qquad (3.13)$$

a distributed "lag" on annual world crop harvest forecasts

$$\sum_{k=0}^{W} d_{2k} \cdot \hat{Q}_{t-k} \qquad (3.14)$$

and a random element U_{At}. That is

$$SP_{t,\tau} = \sum_{k=0}^{n} d_{1k} \cdot P_{t-k,\tau} + \sum_{k=0}^{W} d_{2k} \cdot \hat{Q}_{t-k} + U_{A,t} , \qquad (3.15)$$

where the d's are coefficients, k denotes the lag, n and W are the maximum lengths of the price and information "lags," respectively, and $U_{A,t}$ is a random element.

Now, several comments are in order. First, there are a number of anticipated spot prices. Indeed, as many as there are futures prices covering a period of up to eighteen months. For ourpurposes, we will use the nearest futures contract price as the proxy for all futures prices.

Second, as noted earlier, the forecast of the annual crop harvest made in month t, $\hat{Q}_t$ is the sum of the annual crop harvest forecasts for each country in month t. That is

$$\hat{Q}_t = \sum_{j=1}^{J} \hat{Q}_t^{(j)} \qquad (3.16)$$

Third, crop forecasts are "constructed" for each month of each crop year from the historical forecasts. In the baseline case, the published wheat production forecasts[20] are used

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[20] From: Commonwealth Secretariat's Grain Bulletin.

wherever possible. Gaps are filled in by the methods described in Chapter 2. In the improved case, the forecasts are simulated using a constructed set of "errors" and the published final USDA or FAO estimates for the relevant years. When Q is the true harvest (we suppress the index of crop year for simplicity) in year T let $\hat{Q}_t$ be the constructed forecast of Q for month t of that year. The properties of these constructed forecasts are fully documented in Chapter 2 and Appendix A.

Upon substitution of (3.15) in (3.10) and (3.11) above, the demand and supply of futures contracts can be expressed as functions of the harvest forecasts:

$$L_{t,T} = L[\overline{P}_t, Q, \hat{Q}_t, r] + U_{Lt} \tag{3.17}$$

$$H_{t,T} = H[\overline{P}_t, Q, \hat{Q}_t, I] + U_{Ht} \tag{3.18}$$

respectively, where $\overline{P}_t$ is a vector of current and lagged future prices.

Summarizing, the futures market consists of the following relationships:

Demand	$L_{t,T} = L[\overline{P}_t, Q, \hat{Q}_t, r] + U_{Lt}$
Supply	$H_{t,T} = H[\overline{P}_t, Q, \hat{Q}_t, I] + U_{Ht}$
Futures Price Adjustment	$\Delta_T P_t = P\ [L_{t,T} - H_{t,T}] + U_{Pt}$
Total World Stocks	$I_t = \sum_{j=1}^{J} I_t^{(j)}$

Aggregate Forecasts $\hat{Q}_t = \sum_{j=1}^{J} \hat{Q}_t^{(j)}$

3.5 Linkages

In addition to the above, several other relationships or constraints on the model's variables are necessary to tie the various wheat markets into an integrated world market. First, there are equations relating prices in one region to prices in another region. Assuming international transport costs between region i and j are T_{ij}, these equations are of the form:

$$P_t^{(j)} - P_t^{(i)} - T_{ij} = 0 \qquad (3.19)$$

Second, there is the trade constraint that net exports (imports) summed over all countries add up to zero, i.e.,

$$\sum_{j=1}^{J} Z_{qt}^{(j)} = 0. \qquad (3.20)$$

Next, there is the relationship between hedging and stocks. Short hedges cover their inventory position with future contracts and, by definition, the total amount of short hedging cannot exceed these stocks. These relationships imply that the amount of short hedging cannot exceed world stocks. That is

$$H_t \leq \sum_{j=1}^{n} I_t^{(j)} \tag{3.21}$$

The relationships between the endogenous and exogenous variables are illustrated in Figure 3.1, where the linkages between the various components of the model are presented. The arrows indicate both the linkages and the "direction of causality." As can be seen, the model is simultaneous. That is, one cannot solve for any one dependent variable without solving for, or fixing, all other dependent variables.

With this general structure as a backdrop, the world wheat market model will now be discussed in greater detail.

3.6 The Full Market Model

In the remainder of this chapter, we first review the major issues which have concerned us in the development of the model. Secondly, we select semi-reduced form equations to be used in the estimation procedures. In Chapter 4, we link the model to the objective function to be used in the estimation of benefits. Here, the welfare values for consumers, producers and inventory holders in each country are shown along with regard to the model specified with their aggregation across countries and over time.

3.6.1 Model Overview

A brief recapitulation of the model is in order. As can be expected, the optimal price and flow depend on the demand and supply situations of various countries. Prior

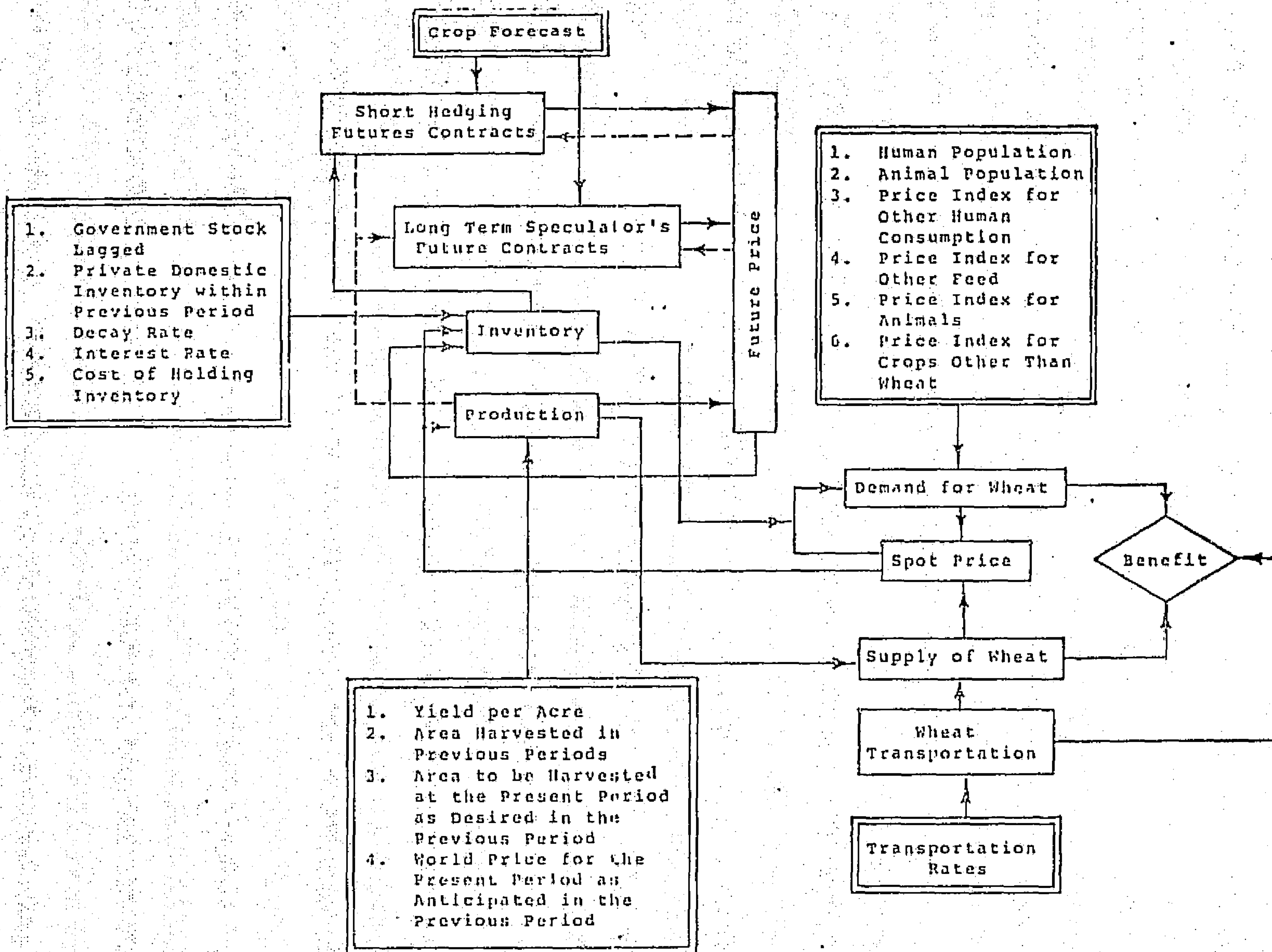

Figure 3.1 Flowchart of Wheat Market Model

information regarding the various supply situations enters the system as "crop forecasts." These forecasts, in general, have error terms whose distributions depend on the state of the world's forecasting capabilities. Thus, the optimal price and flow, as well as the corresponding welfare pertaining to importing and exporting countries, are functionally related to the respective crop forecast capabilities of the various countries involved in world trade.

Since the price and flow of wheat, or any other commodity, are conditioned by the availability of other substitutes (e.g., corn, rye, oats, etc.), it is necessary to take into account the nonzero cross-elasticities of wheat with respect to the prices of its substitutes and complements. These factors are treated in the model as exogenous and appear in the various demand and supply equations.

The spatial equilibrium in the model arises from our aggregate treatment of the world as being divided into two regions: the United States and the Rest of World. This necessary simplification reduces "trade" to United States exports and R.O.W. imports.

Owing to the nature of this study, "time" also is an important dimension in the model. This is essential for a number of reasons. First, wheat can be carried from one period to the next--depending on the inventory holder's reaction to market anticipations. These anticipations can change from month to month and so can the inventory holders' positions. These

changes, of course, influence welfare through price and consumption. Second, the benefits measured in this model, as in reality, depend heavily on the accuracy of market anticipations which, in turn, is a function of crop forecast accuracy. The forecasts play a central role in the model. They represent the best instrument we have for measuring the state of information on the future supply of wheat to the markets. By estimating the model with historical forecasts and then replacing these by simulated forecasts which reflect the improvement in crop information resulting from the ERS system, we have at hand a tool for evaluating the economic effects of crop information in the world wheat markets.

3.6.2 Summary of the Model's Equations

In contrast to the general structures described so far in this chapter, the specific equations used in the model are all linear. This choice was made to improve the estimates of coefficients and to allow more of the modeling effort to be concentrated on the dynamic aspects of the market process. The welfare functions to be described in Chapter 4 are quadratic in the partial equilibrium prices and quantities. Thus the model could be characterized mathematically as (i) a set of linear time-dependent equations with linear constraints representing the dynamics of the market process for each state of information, and (ii) a quadratic welfare analysis of the equilibrium outputs of (i).

In Table 3.1 we summarize the variables and their

Table 3.1 Definitions of Variables

n:	Number of countries
j:	Superscript denoting country; j:1, 2, ...,J
τ or t:	Subscript for time in months, quarters or years
Q_τ:	Production in period t
A_t:	Harvested acres in period t
Y:	Yield per acres
$A^*_{t,\tau}$:	Desired acres harvested for time $t+\tau$ as of time t
P_t:	Spot price at time t
$P_{t,\tau}$:	World price at time $t+\tau$ as anticipated in time t
PI^*_t:	Desired stock of private domestic inventory at time t
PI_t:	Actual stock of private domestic inventory at time t
GI_t:	Government stock of domestic inventory at time t
I_t:	Total stock of inventory
δ:	Decay rate
r:	Interest rate
c :	Cost of holding a unit of inventory over a unit of time
Δ:	Difference operator, i.e., $\Delta X_t = X_t - X_{t-1}$ where X can be any variable
C_t:	Demand for human consumption at time t
F_t:	Demand for feed at time t
E_t:	Demand for seed at time t

Table 3.1 (cont.)

D_t:	Total demand at time t
Z_t:	Wheat exports from United States to rest of world at time t
T_{ij}:	Transportation cost of unit commodity from country i to country j
$\overline{PC}_t$:	Price Index for other human consumptions
$\overline{PF}_t$:	Price Index for other feed
$\overline{PA}_t$:	Price Index for animals (cattle, hog, sheep)
$\bar{P}_t$:	Price Index for crops other than wheat
ρ_{1t}:	Human population at time t
ρ_{2t}:	Population of animals demanding feed at time t
$P_{t,\tau}$:	Futures World Price for time t+τ as of time t
$H_{t,\tau}$:	Short hedging futures contracts for time t+τ as of time t
$L_{t,\tau}$:	Long speculation of demand for futures contracts for time t+τ as of time t
$\hat{Q}_{1t}$:	United States annual wheat crop forecast in period t
$\hat{Q}_{2t}$:	Rest of World annual wheat crop forecast in period t
S_t:	Total supply at time t
CPI_t:	Consumer Price Index at time t

definitions. Note that the superscript j was only used in aggregating the world stocks, imports and crop forecasts. To simplify the notation we omit this index of countries from the table, although it could be applied to any of the variables for which data can be obtained by individual country.

Table 3.2 presents the linear equations which express the relationships among the model's variables as used in the estimation of the value of information to the market. This summary is still preliminary in the sense that the estimation of coefficients by least squares regression techniques can lead us to make reduced selections of variables for inclusion in the final version of the model's driving equations. After describing the estimation strategy in Section 3.6, the details of the estimated forms of these equations follow in Section 3.7.

3.7 Estimation Strategy

Economic phenomena rarely are instantaneous in their impulse--response characteristics, but rather build up over time. Because these lag structures take on a wide range of "shapes," their estimation requires a flexible method. Owing to institutional and "technical" rigidities, e.g., Christmas and weather patterns, some market behavior is likely to exhibit oscillatory "seasonal patterns" that are insensitive to economic factors under normal economic conditions. Capturing these seasonal patterns is important, especially in the context of a monthly model where adjustments to past decisions are of major concern. Finally, meta-market aberrations, such as

Table 3.2 Relationships Among Variables

$$Q_t = A_t Y \tag{1}$$

$$A_t = \alpha A^*_{t-h,h} + (1-\alpha) A_{t-12} \tag{2}$$

where α is exogenous

$$A^*_{t-h,h} = g_h P_{t-h} \tag{3}$$

where g_h is exogenous

$$\Delta I_t = q_I \left[\left(\frac{1-\delta}{1+r}\right)^{\tau} \cdot P_{t,\tau} - P_t - c\tau \right] \tag{4}$$

where q_I and τ are exogenous

$$I_t = PI_t + GI_t \tag{5}$$

$$S_t = Q_t - \Delta I_t \tag{6}$$

$$C_t = \rho_{1t} \left(q_{c,0} - q_{c,1} \cdot P_t + q_{c,2} \cdot \overline{PC}_t \right) \tag{7}$$

$$F_t = \rho_{2t} \left(q_{F,0} - q_{F,1} \cdot P_t + q_{F,2} \cdot \overline{PF}_t + q_{F,3} \cdot \overline{PA}_t \right) \tag{8}$$

$$E_t = q_{E,0} - q_{E,1} \cdot P_t + q_{E,2} \overline{P}_t \tag{9}$$

where the q's are all exogenous to the model

$$D_t = C_t + E_t + F_t \tag{10}$$

$$P_{t,\tau} = b_0 \Delta P_{t-1,\tau} + \sum_{\ell=0}^{12} b_{1\ell} \cdot \left[H_{t-\ell,\tau} - L_{t-\ell,\tau} \right] \tag{11}$$

$$H_{t,\tau} = \sum_{\ell=0}^{12} h_{1\ell} H_{t-\ell,\tau} + \sum_{\ell=0}^{12} h_{2\ell} P_{t-\ell,\tau} + \sum_{j=1}^{2} h_{3j} \hat{Q}_{jt} \tag{12}$$

$$L_{t,\tau} = \sum_{\ell=1}^{12} h_{4\ell} L_{t-\ell,\tau} + \sum_{\ell=0}^{12} h_{5\ell} P_{t-\ell,\tau} + \sum_{j=1}^{2} h_{6j} \hat{Q}_{jt} \tag{13}$$

changes in trade laws, or official procedures, can distort temporarily or shift for all time the behavior of market participants. Failure to account for these aberrations also can cloud the estimation results. Accordingly every effort had to be made to identify those occurrences and remove or adapt to their distorting influence.

3.7.1 Distributed Lag Estimation

Because the impulse-response profiles of economic phenomena rarely are instantaneous but instead tend to build up over time, lead-lag relationships are common in economic models. This is especially true in models where the time units of measure are quarterly or shorter. In this study, several monthly equations with lead-lag relationships were postulated and had to be estimated. The method used to estimate the distributed lag relationships was the Almon technique [2]. This method has practical appeal owing to the great flexibility with which it can estimate various lag structures.

Some impulse-response profiles can follow a decreasing geometric path after some initial impulse, while other lag structures may follow a gradual but decreasing build-up followed by an accelerating decay. The Almon approach can estimate either of these lag profiles and many more elaborate ones as well.

For example, let $Y_t = \sum_{i=0}^{M} w_1 X_{t-i} + e_t$, where w_i is an unknown "lag weight" for X_{t-i}, i=0, 1, ... , m, where the length of the lag, m, is known, X_{t-i} is the value of the

explanatory variable in time $t-i$, and e_t is a random error term. The Almon approach assumes that w_i can be approximated by a polynominal in i. Assuming w_i can be approximated by a second degree polynomial, i.e., $w_i = \gamma_0 + \gamma_1 i + \gamma_2 i^2$, $i=1, \ldots, m$, the above relationship can be written

$$Y_t = \gamma_0 \sum_{i=0}^{M} X_{t-i} + \gamma_1 \sum_{i=0}^{M} iX_{t-i} + \gamma_2 \sum_{i=0}^{M} i^2 X_{t-i} + e_t$$

or

$$Y_t = \sum_{i=0}^{M} (\gamma_0 + \gamma_1 i + \gamma_2 i^2) X_{t-i} + e_t .$$

In the summary of the empirical results to follow we present both the estimated Almon coefficients γ_o, γ_1, and γ_2, along with the lag weights $w_0 = \gamma_1$, $w_1 = \gamma_1 + \gamma_{\substack{1\\2}}$, $w_2 = \gamma_o + \gamma_1{}^2 + \gamma_2{}^4$, $\ldots$, $w_m = \gamma_o + \gamma_1 m + \gamma_2 m^2$, where appropriate.

3.7.2 Seasonal Oscillations

Loosely defined, a seasonal pattern in an economic time series is any oscillation that repeats itself an integral number of times in a period of one year. These movements are encountered in almost every economic time series where the time units of movement are short enough to reveal them. For the most part seasonal patterns owe their presence to forces that are insensitive to economic behavior. Under normal economic conditions, the timing of annual crop plantings and harvests, for example, are dictated largely by weather patterns. Holidays and institutional factors such as tax payment dates also influence the

intra-annual timing of economic activity. Because of forces such as these, seasonal patterns are present in many of our quarterly and monthly time series and their influence on our estimated structures had to be accounted for.

Estimating seasonal movements in economic time series is a field in itself with almost as many technical schemes as there are time series with seasonal patterns. One method that has enjoyed wide and persistent application in behavioral estimating equations (as opposed to purely naive time series estimating equations), and the one employed by this study, is the zero-one dummy variable approach [8]. This method includes variables that take on a value of one for a specific period (e.g. month) of the year for each year in the sample and take on a value of zero otherwise. The number of seasonal dummy variables is one less than the number of time periods a year is divided into. For example, a quarterly equation would use three (3) dummies. The "missing" or 4th seasonal dummy is buried in the regression intercept term and the estimated seasonal dummies are in fact additions to or subtractions from the intercept term at the appropriate time of the year.

To illustrate the approach, consider the quarterly regression equation

$$Y_t = a + bX_t + S_1 + S_2 + S_4 + e_t$$

where Y_t is the dependent variable, a is the intercept, b is the response coefficient on the behavioral explanatory variable X_t, S_i is the coefficient on the i^{th} quarter's seasonal dummy

and e_t is a random element. The explanation of Y_t then would be

$$\hat{Y}_t = a + S_1 + bX_t \quad \text{for the 1st quarter,}$$
$$\hat{Y}_t = a + S_2 + bX_t \quad \text{for the 2nd quarter,}$$
$$\hat{Y}_t = a \qquad\quad + bX_t \quad \text{for the 3rd quarter, and}$$
$$\hat{Y}_t = a + S_4 + bX_t \quad \text{for the 4th quarter.}$$

An analogous scheme is used for monthly equations where 11 dummies would be used.

3.7.3 Aberrations and Structural Shifts

Changes in institutional factors and natural calamities can lead to aberrations and/or structural shifts in economic behavior. Unusually poor harvests owing to bad weather conditions in 1963-1964 and changes in the operating rules of the market place in 1972 are two such examples that were encountered in this study. Because these factors can distort economic behavior but cannot be modelled in a behavioral sense, econometric models are built around, and adapted to them. Typically, and as was done here, these influences were accomodated by the use of dummy variables.

For aberrations that have a temporary effect on the market, zero-one dummy variables are used to "explain" the market during those points in time. Here, the dummy variables take on a value of one during the period of the aberration and take on a value of zero otherwise. The estimated coefficient on these dummy variables is interpreted as a measure of the

aberration and "filters out" its influence on the estimating equation.

Structural shifts or changes in the normal behavior of the market also can be handled with dummy variables. Here, for example, multiplicative and additive dummy variables can be used to capute shifts in the slope and intercept of a regressin equation, respectively, after some institutional change has taken place. Such an estimating relationship would be of the form

$$\hat{Y}_t = a_0 + a_1 + b_0X_t + b_1X_t = e_t$$

where a_1 and b_1 are coefficients on dummy variables that only appear on and after some point in time. Prior to that point in time the estimate of Y_t would be

$$\hat{Y}_t = a_0 + b_0X_t$$

On and after that point in time the estimate of Y_t would be

$$Y_t = (a_0 + a_1) + (b_0 + b_1)X_t .$$

The U.S. equations are presented first. These include, Human Demand, Feed Demand, Seed Demand, Commercial Stocks, and Acres Harvested. The Rest of World equations are presented last. This block of equations contains the estimated equations for Short Hedging, Long Speculation and Futures Price Adjustments.

3.8 Estimation Results: The U.S. Block

The equations estimated for the U.S. were Wheat Demand for Human Consumption, Wheat Demand for Animal Feed, Wheat Demand for Seed, Commercial Stocks and Wheat Area Harvested. Each is summarized below.

3.8.1 Wheat Demand for Human Consumption

The equation estimated for human wheat consumption is presented in Table 3.3. The equation was estimated using quarterly data from the first quarter of 1961 to the fourth quarter of 1972. Because the dependent variable did not exhibit a trend over the estimation period, the relationship was not estimated in first difference form.

For the most part, wheat demand for human consumption is an intermediate one, e.g., demand by bakers to produce bread. It is reasonable, therefore, to expect this demand to adopt to market stimuli somewhat more slowly than final demands for immediate consumption. The lagged dependent variable reflects this characteristic and has a "stable" response co efficient of .2417, implying a finite adjustment to some past market impulse. Because the demand for wheat for human consumption is an intermediate demand, it also is reasonable to expect delays between the purchase of wheat, say by a baker, and the physical processing of the commodity. A two quarter lag on price. i.e., a midpoint lag of five months, is not outside the range of reason for a delay between spot purchases, delivery and utilization by processors and wheat product producers. The coefficient of -.2498 on the price of wheat has

Table 3.3 Human Demand for Wheat in the U.S.

(t in quarters : 48 values used for estimation)

Dependent Variable	$V_t = C_t/\rho_{1t}$	U.S. Per Capita Human Demand for Wheat
Independent Variables	V_{t-1}	V_t Lagged One Period
	P_{t-2}	Spot Price Lagged Two Periods
	W_t	Constant Dollar Per Capita Income in the U.S.
	D644 D651	Dummy Variables for 4th Quarter '64 & 1st Quarter '65
	D1,D2,D4	Seasonal Dummies

Estimated Equation:

$$V_t = \underset{(6.6)}{713.8} + \underset{(2.1)}{0.2417}V_{t-1} - \underset{(-1.9)}{0.2498}P_{t-2} - \underset{(-4.6)}{6674}W_t$$

$$+\underset{(6.4)}{96}D644 - \underset{(-5.8)}{110}D651 + \underset{(2.6)}{23}D1 + \underset{(2.8)}{17}D2 - \underset{(-6.2)}{39}D4$$

$R^2 = 0.83$
D-W = 1.56

the "right" sign and corresponds to m thly price elasticities of demand of approximately -.2181 in the short-run-.288 and after all auto-regressive feedbacks have been accounted for, respectively. These results lie with the range of elasticities found by others.

The dummy variables capture seasonal movements and filter out the effects of pronounced U.S. Government wheat sales in the last quarter of 1964 and first quarter of 1965.

All variables are statistically significant at the 90 percent confidence level or better and the entire equation provides a good fit as evidenced by the high R^2 and strong F statistic. The Durbin-Watson statistic is low, suggesting possible autocorrelation.

3.8.2 Feed Demand for Wheat Per Animal in the U.S.

The U.S. feed demand for wheat equation is presented in Table 3.4. This equation was estimated using quarterly of 1972. Because the number of animal feed over this period, feed demand had a noticeable upward trend and therefore the behavioral variables were used in first-difference form..

Feed demand is an intermediate demand and therefore likely to exhibit lagged adjustments to market influences and delays between purchase and usage. Here, the lagged

Converting prices and quantities back to monthly levels and using 1972 data, the coefficient of -.00000433 on lagged wheat price corresponds to short and long-run price elas-

Table 3.4 Demand for Wheat and Annual Feed in the U.S.

(t = quarters ; 34 quarters from 64/3 to 72/4 used)

Dependent Variable	$V_t = \Delta F_t / \rho_{2t}$	First Difference of Feed Demand per Animal
Independent Variables	V_{t-1}	V_t Lagged One Period
	$W_{t-2} = \Delta P_{t-2}$	First Differnce of Wheat Price Lagged Two Periods
	D1, D2,...D7	Seasonal Dummies and "Special" Time-dependent Dummies

Estimated Equation

$$V_t = \underset{(3.02)}{0.00} - \underset{(-2.93)}{0.50}V_{t-1} - \underset{(-1.96)}{0.0000043}W_{t-2}$$

$$-\underset{(-1.87)}{0.0002}D1 + \underset{(6.84)}{0.0015}D2 - \underset{(-1.63)}{0.0002}D3 + \underset{(0.38)}{0.0001}D4$$

$$-\underset{(-4.66)}{0.0005}D5 + \underset{(3.68)}{0.0007}D6 - \underset{(-3.05)}{0.0006}D7$$

$R^2 = 0.96$
D-W = 1.95

ticities of demand of -3.048 and -4.579, respectively. These elasticities are well within reason, as there are plentiful substitutes for animal feed.

The dummy variables capture a seasonal pattern that appears to have shifted in 1968. The dummy variables D_1, D_3, D_5 and the constant C capture the seasonal pattern from April 1964 through April 1967. The dummy variables D_2, D_4, D_6 and D_7 capture the seasonal pattern from January 1968 through April 1972.

The "t" statistics on the estimated coefficients, with the exception of one seasonal dummy variable, imply stable and significant estimates at the 90% confidence level or better. The overall equation fits the data well: the R^2 is very high as is the F statistic, and the Durbin-Watson statistic is almost perfect.

3.8.3 Seed Demand for Wheat in the United States

The Seed Demand for Wheat equation is presented in Table 3.5. This equation was estimated using annual data from 1962 to 1971. Because of trends in some of the variables, this equation also was estimated in first differences.

Seed demand is a derived demand and as such is likely to include an adaptive portion as well as direct or delayed responses to prices. The coefficient on lagged seed demand implies stable adjustments to past phenomena influencing the demand for seed, and the one year length of the lag conforms with physical crop harvest patterns.

Table 3.5 Seed Demand for Wheat in the U.S.

(t = years ; t=1962 to 1971 used for estimation)

Dependent Variable	ΔE_t	First Difference of Seed Demand in U.S.
Independent Variables	ΔP_t	First Difference of Spot Wheat Prices
	$\Delta P_{t,1}$	First Difference of Futures Wheat Prices
	$\Delta \overline{PC}_t$	First Difference of Average Price of Substitutes
	ΔE_{t-1}	First Difference Seed Demand Lagged One Period

Estimated Equation

$$\Delta E_t = \underset{(2.24)}{204.8\Delta P_t} + \underset{(1.29)}{117.4\Delta P_{t,1}} - \underset{(-1.21)}{149.9\Delta\overline{PC}_t} + \underset{(1.06)}{0.296\Delta E_{t-1}}$$

$R^2 = 0.61$
D-W = 2.12

The positive coefficient on wheat futures prices is what one would expect: farmers will plant in anticipation of rewards and wheat futures prices are an indicator of these rewards. Obversely, the negative coefficient on the futures prices of alternative crops reinforces the evidence that farmers will shift away from wheat production and therefore from seed demand as say future soybean prices become more attractive. The positive relationship between seed demand and current wheat price is difficult to pin down. It may be a reflection of the market's reaction to anticipated future rewards.

The spot price elasticity of demand in this equation, using 1972 data, is +.1065 in the short-run and +.1512 when all auto-regressive feedback is accounted for. The futures price elasticities of seed demand also are positive and about half the size of the spot price elasticities. Together they suggest seed demands that are moderately responsive to prices.

Although some of the "t" statistics are strong, multicollinearity is present between the price variables even in their first-difference form. Nevertheless, the aggregate equation is a close fit with an F statistic significant at the 10% level and an acceptable Durbin-Watson statistic indicating little residual first order serial correlation.

3.8.4 Demand for Commercial Stocks in the United States

The Commercial Stock equation, presented in Table 3.6, was estimated using quarterly data from the last quarter of 1961 to the last quarter of 1972. Because the dependent

Table 3.6 Demand for Commercial Stocks in the U.S.

(t = quarters; 61/4 to 72/4 used in estimation)

Dependent Variable	PI_t	U.S. Commercial Stocks
Independent Variables	$U_t = P_t - P_{t,\tau}$	Spread Between Futures and Spot Prices for Wheat
	PI_{t-1}	PI_t Lagged One Period
	D1,D2,D4	Seasonal Dummies

Estimated Equation

$$PI_t = \underset{(0.58)}{0.898U_t} + \underset{(13.7)}{0.898PI_{t-1}} - \underset{(-2.4)}{44.0D1} - \underset{(-3.2)}{57.7D2} - \underset{(-1.4)}{25.2D4} + 61.4$$

$R^2 = 0.84$
D-W = 2.12

variable has a downward trend in the first half of the period and an upward trend in the second half of the period, and because the explanatory variables do not exhibit smooth and pronounced trends over the sample period, the equation was not estimated in first difference form.

The significance of the lagged dependent variables attests to the strength of the stock adjustment hypothesis. The coefficient on the lagged dependent variable corresponds to stock adjustment coefficient of about -.102 which implies a stable stock adjustment (leading to a finite limit) to past market stimuli.

The difference between the futures and spot price of wheat enters the equation with the right sign but with a very low "t" statistic. However, the introduction of the variable did raise the R^2 and lowered somewhat the "t" statistics on the other explanatory variables in the equation. These results appear to reflect the cumulative effects of modest collinearity between the price spread variable and the other explanatory variables. The seasonal dummies capture a stable seasonal pattern and the R^2, F statistic and Durbin-Watson statistic together portray a strong overall equation.

The elasticity of demand for commercial stocks, with respect to the difference between the futures price and the spot price, is .0597 in the short-run and .5697 when all auto-regressive effects work themselves out. These results suggest that inventory holders are relatively insensitive to changes in the

spread between futures prices and spot prices, in the short-run but relatively sensitive to changes in this price spread in the long-run. These results seem quite reasonable when one recalls that many inventory holders also are hedgers and likely to be risk averse. Finally, zero marginal carrying costs were estimated in earlier ECON studies and these results are assumed to apply here.

3.8.5 Area Harvested in the United States

The equation describing United States Area Harvested for wheat is presented in Table 3.7. This equation was estimated using annual data. The equation was estimated in stock adjustment form from 1963 to 1974.

The results indicate that the area harvested for wheat is not highly responsive to futures prices. First, United States Government farm programs are designed, in part, to safeguard the financial integrity of the farm sector. In part, this is effected through a soil bank program and our regression estimates no doubt reflect these "constraints." Second, in all but one or two years in the sample, futures prices were quite stable and the regressions cannot help but be bent toward this history.

The coefficient on lagged area harvested of -.4651 implies a stable and fairly rapid "stock adjustment" as histor-

Table 3.7 Area Harvested for Wheat in the U.S.

(t = years ; data from 1963 to 1974 used in estimation)

Dependent Variable	ΔA_t	First Difference of Area Harvested
Independent Variables	$P_{t,\tau}$	Futures Price of Wheat
	A_{t-1}	Area Harvested Lagged One Period
	D67	Dummy Variable

Estimated Equation

$$\Delta A_t = \underset{(1.2)}{5015} + \underset{(4.6)}{25.55}P_{t,\tau} - \underset{(-2.4)}{0.465}A_{t-1} + \underset{(2.9)}{3640}D67$$

$R^2 = 0.74$

D-W = 2.57

ically has been the case. The dummy variable for 1967 was included to filter the effects of market aberrations for that year.

Although the Durbin-Watson statistic suggests some possible negative serial correlation, the estimated equation is strong with an R^2 of 0.74, F statistic of 11.18 and strong "t" statistics on the behavioral explanatory variables.

3.8.6 The Rest of World

3.8.6.1 Rest of World Demand

The per capita demand for wheat by the rest of the world was estimated from 1961 to 1970, using annual data. In Table 3.8, at first glance these results may seem high. However, the aggregate rest of the world regards soybeans and rice as stronger substitutes for wheat than the United States and these differences in tastes, no doubt, are reflected in these results. The findings are further supported by the cross-elasticities of demand with respect to the price of substitutes. Here, the coefficient of +1043 and the price of substitutes implies short and long-term cross-elasticities of wheat demand with respect to the price of substitutes of +7.62 and +5.41, respectively.

3.8.7 Rest of World Area Harvested

The Rest of World Area Harvested equation is given in Table 3.9. The equation was estimated in "stock adjustment" form from 1961 to 1970, using annual data. The overall equation fits the data reasonably well with an R^2 of .34 an, F sta-

Table 3.8 Rest of World Demand for Wheat

(t in years; 1961 to 1970 used in estimation)

Dependent Variable	(Row) $V_t = D_t/\rho_{1t}$	Per Capita Rest of World Demand for Wheat
Independent Variables	V_{t-1}	V_t Lagged One Period
	$P^*_{t-1} = P_{t-1}/CPI_{t-1}$	Deflated Price of Wheat Lagged One Period
	$\overline{PC}^*_{t-1} = \overline{PC}_{t-1}/CPI_{t-1}$	Deflated Average Price of Soybeans and Corn Lagged One Period

Estimated Equations

$$V_t = -0.41V_{t-1} - 683.4P^*_{t-1} + 1043\overline{PC}^*_{t-1} + 3510$$
$$(-1.9) \qquad (-3.7) \qquad (3.0) \qquad (4.6)$$

$R^2 = 0.56$
D-W = 2.45

Table 3.9 Rest of World Area Harvested

(t in years: 1961 to 1970 used in estimation)

Dependent Variable	ΔA_t	First Difference of Rest of World Area Harvested
Independent Variables	A_{t-1}	A_t Lagged One Period
	$P_{t-1,\tau}$	Futures Price of Wheat Lagged One Period

Estimated Equation

$$\Delta A_t = \underset{(-1.8)}{-0.34 A_{t-1}} + \underset{(1.7)}{3838 P_{t-1,\tau}} + \underset{(1.7)}{60935}$$

$R^2 = 0.34$
D-W = 1.99

tistic significant at the 10% level and an excellent Durbin-Watson statistic. In addition, the arguments in the equation have coefficients of reasonable size and signs one would expect a priori.

The lagged futures prices last year lead to more acres harvested this year. In terms of elasticities, the short and long-run futures price elasticities of wheat demand are .03179 and .088, respectively. These elasticities are higher than in the United States as one would expect. Much United States production response to prices, no doubt takes the form of improved seed and fertilizer--alternatives that are not within reach of the less affluent rest of the world.

3.8.8 The World Futures Market

The world futures market was analyzed in three equations: a price adjustment equation, a short-hedging equation and a long speculation equation. The results of the price adjustment equation were selected for use in the model since they gave a meaningful relationship between the futures price movements and crop forecasts. The wheat futures price used here is the price on the nearest maturing wheat futures contract. The short-hedging and long speculation variables are for all-wheat futures contracts.

3.8.9 Price Adjustments for Futures Contracts

The price adjustment equation for futures contracts, presented in Table 3.10, was estimated in first differences using a monthly data from February 1962 to June 1971. Apart from

Table 3.10 Wheat Futures Price Adjustment

(t= months; Feb. 62 to June 71 used in estimation)

Dependent Variable	$\Delta P_{t,\tau}$	First Difference of Futures Price of Wheat
Independent Variables*	$P_{t-1,c}$	$\Delta P_{t,\tau}$ Lagged One Period
	$\Delta\hat{Q}_t^{(US)}$	First Difference of US Crop Forecasts
	$\Delta\hat{Q}_t^{(ROW)}$	First Difference of ROW Crop Forecasts

Estimated Equations

$$\Delta P_{t,\tau} = \underset{(0.79)}{1.43} + \underset{(2.32)}{0.20}\Delta P_{t-1,\tau} - \underset{(-1.37)}{0.33}\Delta\hat{Q}_t^{(US)} - \underset{(-1.30)}{0.089}\Delta\hat{Q}_t^{(ROW)}$$

$R^2 = 0.38$
D-W = 1.81

*Omitting the eleven monthly dummies and four "special" dummies. See Appendix B for complete regression results.

the special events and seasonal cycles reflected in the dummy variables (not shown in Table 3.10) the main effect explaining the futures price first differences are:

(a) a positive partial correlation (0.20) with the futures price first difference lagged one month (t - statistic = 2.32)

(b) a negative partial correlation (-0.33) with the first differences of U.S. crop forecasts (t - statistic = -1.37)

(c) a negative partial correlation (-.089) with the first difference of R.O.W. crop forecasts (t - statistic = -1.30)

These partial correlations are in the right direction and are moderately significant. The overall "fit" expressed by $R^2 = 0.38$ is not too bad for a first-difference equation. The same equation when not estimated in Δ's gave an $R^2 = 0.96$, but the lagged futures price was so dominant (t - statistic = 20) that the difference form was held preferrable. It is interesting that the price adjustment responds more vigorously to U.S. crop forecast than to R.O.W. forecasts. This could be a result of the aggregation of many countries in the R.O.W. or it could reflect the greater degree of confidence the market shows toward U.S. forecasts.

3.8.10 Long Speculation and Short Hedging

The supply and demand for futures contracts were analyzed in relation to the quality of crop forecast information as discussed in Section 3.4.4. The estimation results are shown in Tables B.9 and B.10 of Appendix B. While the statistical fit was quite satisfactory, these equations were not used in the model since they did not add substance to the theory already developed in the price adjustments equation (Table 3.10).

4. THE BENEFITS FROM IMPROVED WORLDWIDE WHEAT PRODUCTION FORECASTS

4.1 Introduction

The value of information can be measured using the economic theories of consumer and supplier surpluses.[21] Let us assume Figure 4.1 illustrates a typical demand curve for a commodity. At any point in time, a consumer is faced with a budget constraint that places a limit upon the amount of goods and services he can command (in the market). The consumer, therefore, views his consumption of any one item as a decision to forego other alternatives or opportunities that are available to him. Hence, the consumer's "problem" may be viewed as one of minimizing his "opportunity costs." Anything that can reduce the opportunity costs of actions (decisions) provides economic benefits. As shall be shown, this is precisely the role that information plays and is the means by which it ultimately obtains its economic value.

Returning to Figure 4.1, the demand curve illustrates the amount of an item a consumer will buy at a given price or, obversely, the price a consumer will pay for a given quantity. Owing to diminishing marginal utility, the consumer may be willing to pay price P_1 for the first unit consumed, but pay only

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21 To minimize semantic issues we adhere to the most commonly used terminology, although we may have serious reservations about the implied meaning of the terms consumer and supplier "surplus." The substance -- by whatever name -- when correctly dealt with <u>over time</u>, is quite real in whatever economic system.

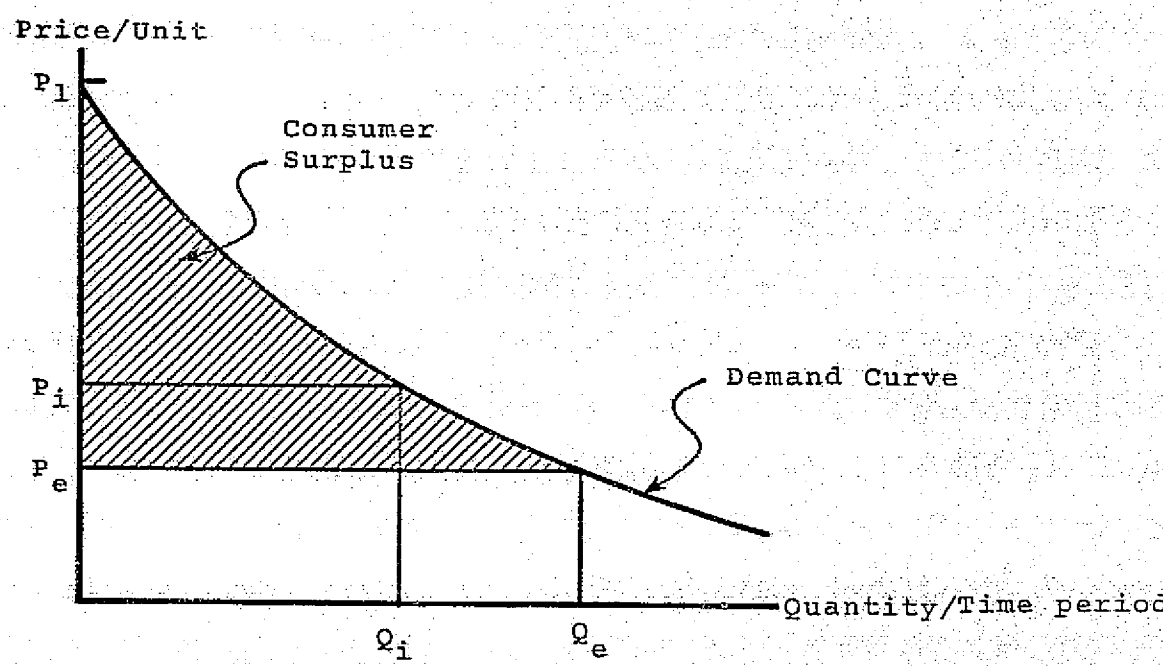

Figure 4.1 Consumer Surplus

price P_i for the i^{th} unit consumed. Assuming money is a firm measuring rod of utility, the existing market price is P_e and consumption is Q_e, then the shaded area below the demand curve continuum and above the market price depicts the consumer surplus (or negative opportunity costs) received by the consumer by paying price P_e on all Q_e units. The full money value to the consumer is the entire area under the demand curve up to the quantity purchases. The cost to the consumer, however, is only P_eQ_e. The difference between the full money value and the amount paid is the surplus.

If the market equilibrium price and quantity were P_1 and Q_1 respectively and shifted to P_2 and Q_2 as shown in Figure 4.2, consumers would reap the "benefit" or incremental consumer surplus indicated by the shaded area. The area defined by $(P_1-P_2)Q_1$ are benefits to the consumer simply from the drop in price on his already existing level of consumption (Q_1), if no additional units were purchased in spite of lowered price. The shaded area corresponding roughly to 1/2 (P_1-P_2) (Q_2-Q_1) represents the incremental surplus to consumers from additional purchases (ΔQ) owing to the more attractive price.

The above discussion applies only to consumers' benefits. Suppliers' and society's benefits, however, need additional consideration but may be viewed in a similar fashion.

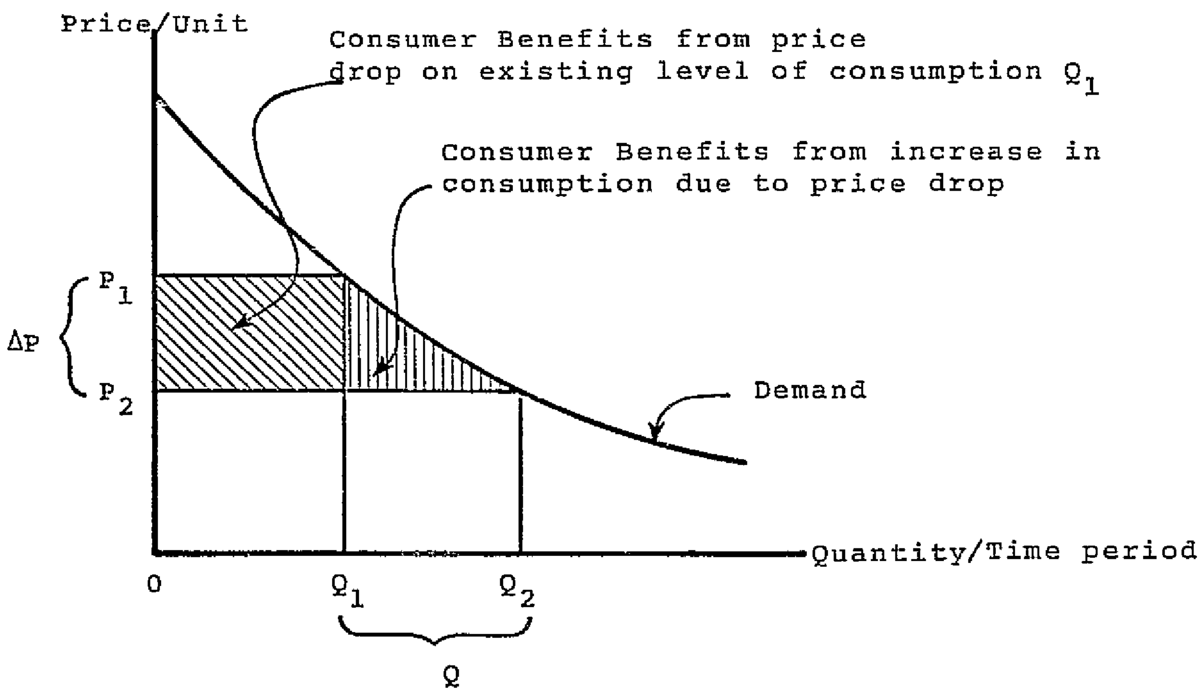

Figure 4.2 Incremental Consumer Benefits From a Downward Shift in Prices

In the earlier example* of the wheat farmer, the opportunity cost of plowing under his field was the net revenues foregone by the action. If, as the example contended, the market prices were relatively low (owing to a forecast of large crop), then, the opportunity costs of the plowing-under decision would be zero or even negative (i.e., the farmer would not make as much profit if he decided to fully harvest). But, as the example would go on to show, the actual state of the world was not a bountiful harvest and the market price was higher than expected when the farmer would have sold his crop. Thus, the realized or ex-post opportunity cost of plowing-under was positive and the farmer should have harvested and brought the wheat to market. The value to the farmer of the "better" or more accurate information is his net revenue obtained from the change in decision due to the information.

In Figure 4.3, DD is the aggregate demand function for a commodity and the initial market supply/demand equilibrium is such that Q_1 is demanded at price P_1. At the point (P_1, Q_1), the following conditions prevail: consumers are enjoying a net benefit (or consumer surplus) of A, and suppliers are enjoying a net benefit of B + E, the so-called producer or supplier surplus [40, 45]. This latter "surplus" is the difference between total revenues obtained from selling Q_1 at price P_1 and the cost of supplying those items represented by the area below

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*See Overview volume of this report.

the supply curve and above the horizontal axis between O and Q_1.

Now, suppose the supply function shifts from s_1 to s_2, indicating that (in general) each unit of output can be provided at less cost than before. The market will move to a new equilibrium situation and the following conditions will prevail. Referring to Figure 4.3, consumer surplus increases from A to A + B + C + D and producer surplus changes from B + E + E + F.

Certainly, the consumer reaps benefits from the lowered prices, since the sum of A, B, C, and D is greater than A by itself, i.e., $A + B + C + D > A$. The change in producer's benefits, however, is not necessarily positive since $B + E \gtrless E + F$. The result depends upon the elasticities of the supply and demand curves. The net benefit to society would be $B + C + D + F = B$ or $C + D + F$ and also depends on the elasticities of supply and demand.

For any given set of supply and demand relationships, we can measure the surpluses accruing to consumers, suppliers and society assuming, of course, that money is an adequate yardstick to measure satisfaction. Assuming further that this "yardstick" is equally valid for all countries, benefits to other societies can be measured by adding up the benefits to the individual members of the group.

By the same token, consumer and supplier surpluses can be used to measure the benefits or losses to consumers, suppliers, societies and groups of societies from changes in

and/or demand relationships. There remains an important topic for discussion: at which level shall consumer and producer surplus be measured? Directly where the distortion (a form of tax) occurs, (in this case misinformation on wheat crops) or indirectly through the distortions this misinformation (tax) causes in the cost and level of consumption of final goods.

The first approach is best exhibited by Albert Rees and Arnold C. Harberger [37, 38 and 97] in their work on the effect of unions on labor costs (Rees) and the measurement of waste and tax effects (Harberger). Herein the authors proceed to measure the economic loss (costs) of distortions, waste and taxes directly at the level of the distorted <u>input markets</u> themselves. Basic to the work of both authors is a treatment of <u>economic costs</u> of waste and taxes (or misinformation in our case) as a simple money measure of the "deadweight" loss that the distortion imposes on the sum of the areas analogous to consumers' and producers' surplus, i.e., the demand and supply functions (schedules, correspondences) of the intermediate good are used directly for measuring economic loss. In our study we follow this approach: we estimate demand and supply functions for wheat (food, feed and seed) and the distortion misinformation causes to the system. We do not estimate the demands for bread, noodles, whiskey, etc. and then aggregate economic losses (costs).

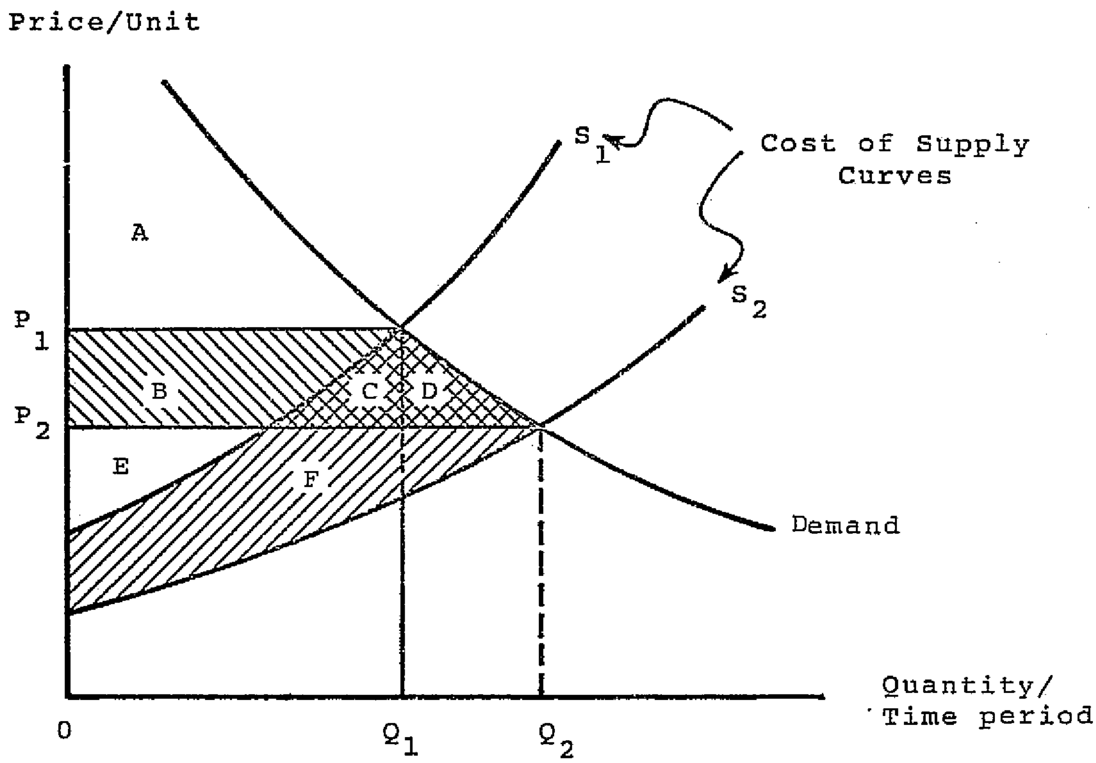

Figure 4.3 Increments in Consumer and Producer Surpluses from a Downward Shift in the Cost of Supply

The second approach uses the more abstract concept of a social welfare function to measure the aggregate loss of welfare by input market distortions. This second approach has been used in work by Harry Johnson [63], Albert Fishlow and Paul David [28], Jagdish Bhagwati and V.K. Ramaswami [9].

In his work on the economic costs of input market distortions, Daniel Wisecarver [127] shows that the first approach yields equivalent results to the second approach in most cases. In the cases where the two approaches yield different results, the first approach is more conservative, i.e., understates the cost of distortions (misinformation) when compared to the second method. For this reason -- as well as our agreement in principle -- we use the first method in this study: given the derived demand curve for an agricultural crop (wheat), the economic loss (cost) of inaccurate information is correctly, completely and most readily measured by the relevant area between the demand and supply functions for agricultural crops (wheat). This proposition is founded on the most recent economic literature.

4.2 Benefits as Negative Losses

In the previous section, consumer and producer surpluses were shown to be a quadratic function of crop forecast errors. We will adopt the rule of referring to the error components in the welfare measures as the "welfare loss," assuming of course that their net welfare effect is negative. A re-

duction in this "loss" is a natural measure of "gains" or "benefits" to the various market participants. It is this notion of benefits that we will use in this study.

The measurement of benefits, as defined in this study, can be described in terms of the incremental changes in consumer surplus (CS) and producer surplus (PS). We define first the appropriate integrals of demand and supply functions:

$$CS_t = \int_0^{X_t} \left(P(\xi) - P_t\right) \, d\xi,$$

and

$$PS_t = \int_0^{X_t} \left(P_t - MC(\Psi)\right) \, d\Psi,$$

respectively, where P (X) is the demand curve, MC (X) is the marginal cost (supply) curve and P_t is the equilibrium price at which supply equals demand at time t.

In the partial equilibrium analysis of this study, X_t will be the same in both calculations and represent the quantity supplied to the world wheat markets in one period (a month) at time t.

The wheat market model described in Chapter 3 generates the equilibrium prices P_t and quantities X_t for the historical crop forecasting capability (B=Baseline) and the improved crop forecasting capability -- using remote sensing from space (I=Improved). The annual benefits to the consumers and producers may be calculated over twenty-four monthly periods as:

$$\Delta CS = \underset{t=1,2,\ldots,24}{\text{AVG}} (CS_t^I - CS_t^B)*12$$

$$\Delta PS = \underset{t=1,2,\ldots,24}{\text{AVG}} (PS_t^I - PS_t^B)*12$$

The precise method for averaging will be detailed in the next section. Combining the consumer and producer benefits gives the annual national benefits: $NB = \Delta CS + \Delta PS$.

The above benefits calculation can be performed from the point of view of the United States or from the point of view of the wheat-importing countries (rest of world) using the appropriate demand functions and marginal cost-of-supply functions. Before considering the differing national viewpoints regarding the economic effects of improved crop forecasts, we need to consider in greater detail the mechanism by means of which improvements in information can be translated into national benefits.

There are several types of benefits that can be identified in an economic context. In general, these benefits fall into two broad categories: "distribution benefits" and "production benefits." These "rewards" are distributed between countries and the various economic players within a country in different proportions. In the following paragraphs we present distribution and production benefits to consumers and suppliers within a country and to exporting and importing countries.

4.3 Types of Benefits

In the following paragraphs we present several types of domestic and trade benefits that may arise from improved crop forecast information. Each of these is described and illustrated below.

4.3.1 Domestic Distribution Benefits: The Linear Demand Symmetric Behavior Case

"Distribution benefits" arise when a given (perfectly inelastic) supply of some commodity is consumed fully in a period world that responds to imperfect forecasts as if they were true. To develop the theory without unnecessary complexity, we will use only two periods. The losses on which these benefits are derived are illustrated in Figures 4.4(a), (b), (c) and (d). In the upper left-hand chart, (a), the true supply and demand schedules for a commodity are presented. Here the equilibrium price and quantity are P_0 and Q_0, respectively. Now, suppose that in period 1, supply is believed to by Q_1 and the market equilabrates at price P_1. This is shown in the upper right-hand chart of Figure 4.4. Here the shaded area indicates the period 1 welfare loss, (the sum of the consumer and supplier losses) owing to the underestimate of supply. By the next period, the underestimate of supply has been detected and the supply of the commodity surges to an "effective two-period level" of Q_2 with a new lower price of P_2. This reaction is shown in chart (c) in the lower left-hand corner of Figure 4.4. Here the shaded area indicates the welfare gain in the second period.

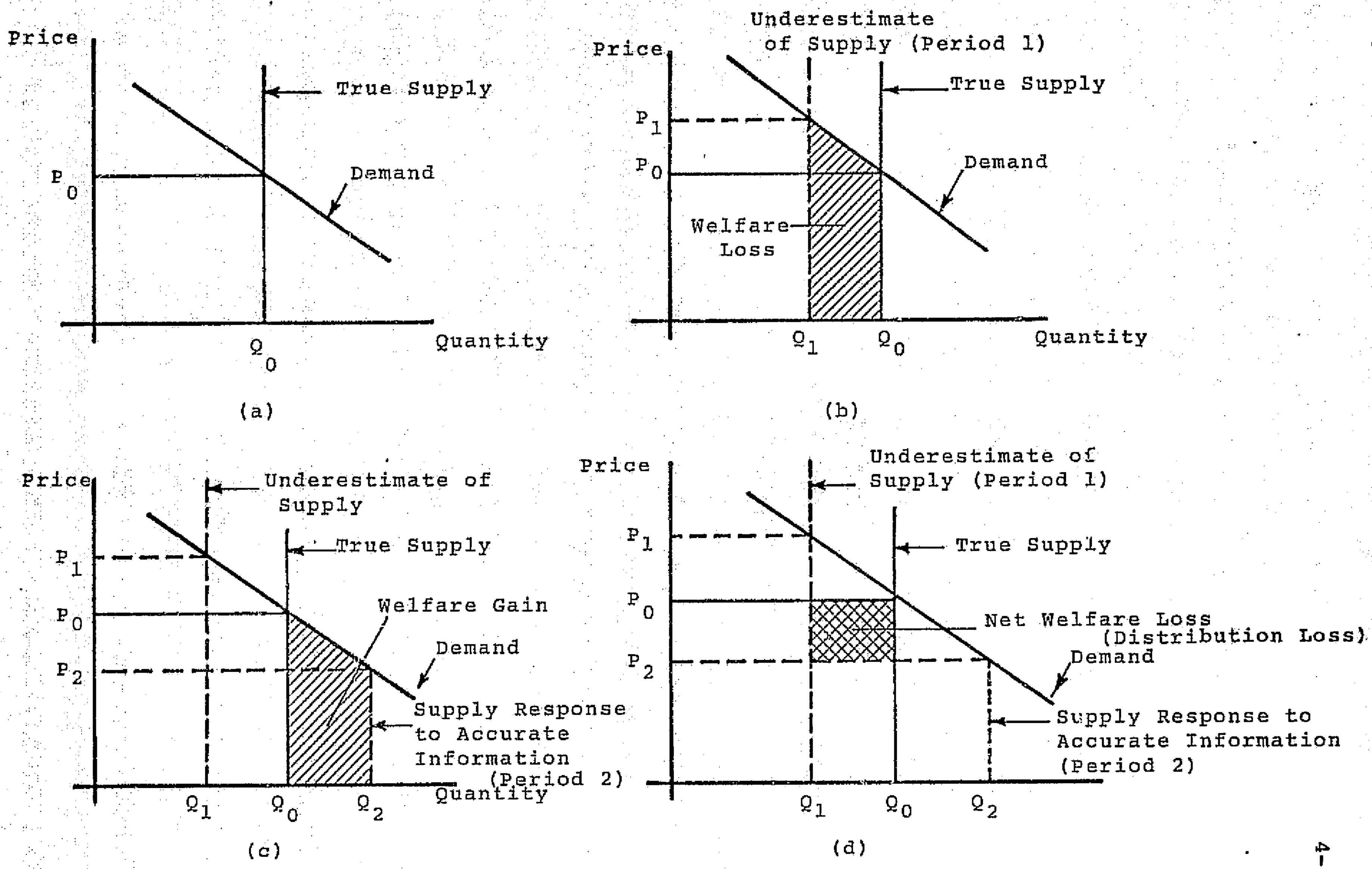

Figure 4.4 "Distribution of Losses"

Without regard to discounts, etc. the net welfare loss to society owing to misinformation is the shaded area in Chart (d) in the lower right-hand corner of Figure 4.4.[22]

In this admittedly simple world, the net welfare loss indicated the potential welfare gain to society from perfect information at the outset. A partial improvement in information, of course, will capture only a portion of the original welfare loss or potential welfare gain. This partial improvement is illustrated in Figure 4.5. In this figure the original welfare loss or potential welfare gain is the shaded area bounded by P_0, P_2, Q_1 and Q_0. This loss, of course, corresponds to some original forecast error probability density function of the crop. Improved information is reflected in a narrower or tighter forecast error distribution. The reduction in forecast error variation implies a new and smaller welfare loss (the Residual Welfare Loss) bounded by P_0, P^*_2, Q^*_1 and Q_0. The difference between the original welfare loss and the residual welfare loss is the welfare gain or "benefit" owing to improved information and is illustrated in the lower right of Figure 4.5.

The above relationships have several implications that deserve special mention. First, the results are the same re-

[22]This is similar to the Hayami-Peterson [43] treatment of the subject.

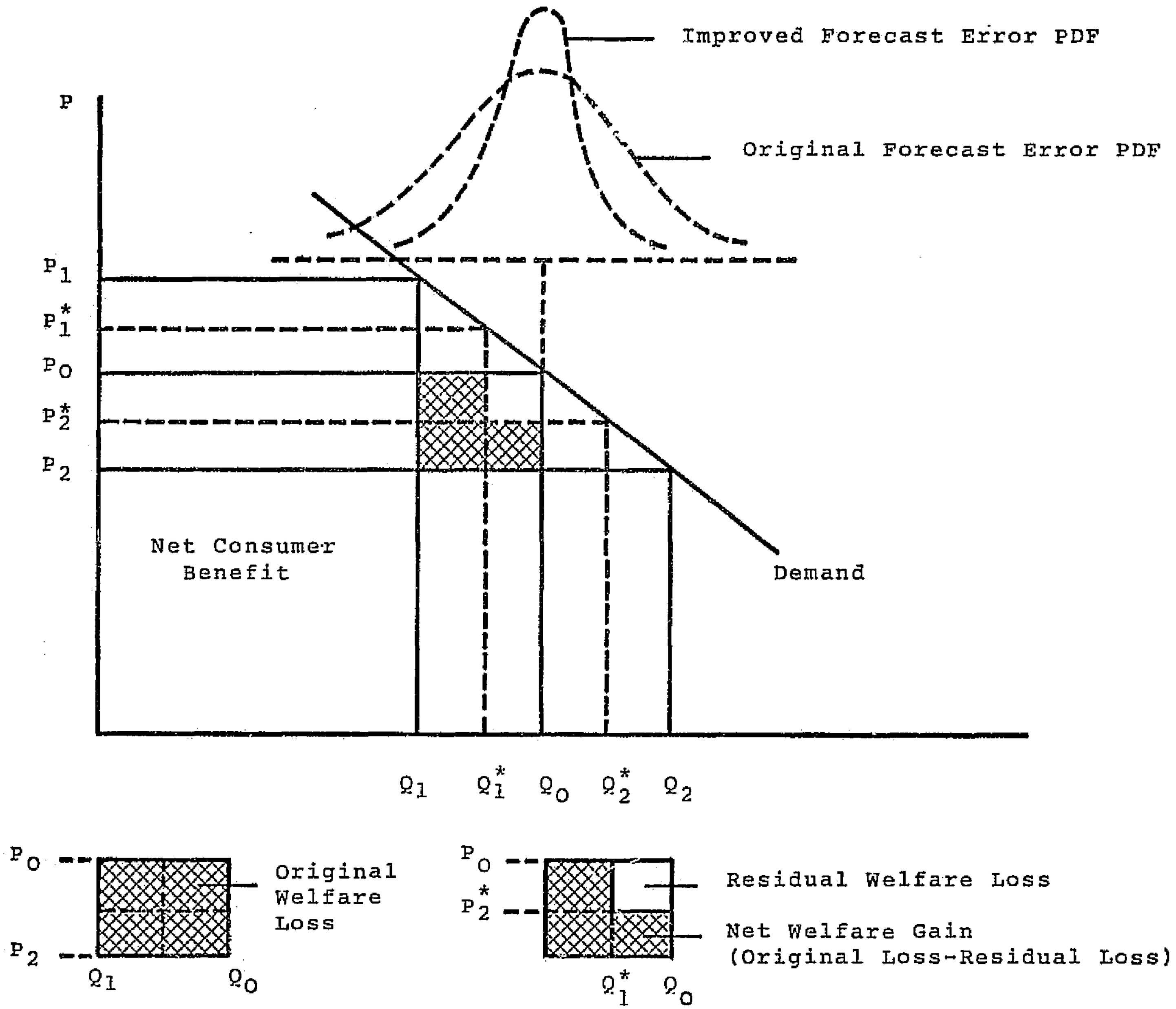

Figure 4.5 Distribution Benefits From a Partial Improvement in Information

gardless of the sign of the original forecast error. Second, consumers lose from reduced supply variation, while suppliers gain twice the consumer loss. This follows directly from the linear downward sloping demand function and the assumed symmetric reaction of consumers to over and underestimate errors with regard to their consumption over time. This loss was noted some time ago by Waugh [125] and can be shown easily.

With regard to Figure 4.6, consumer surplus over two periods with perfect information would be 2(A+B+E). With imperfect information, resulting in quantity fluctuations between Q_1 and Q_2, consumer surplus over two period would be A + (A+B+C+E+F+H). Since B = C and E = H the net benefit to consumers from perfect information would be -F. That is, consumers would lose F in "surplus" from perfect information. Obversely, consumers benefit by amount F from imperfect information.

With regard to Figure 4.6 once again, supplier surplus with perfect information over two periods would be 2 (C+D+F+G). With imperfect information, suppliers surplus for two periods would be (B+C+D) + (D+G+I). Since B + C and G = I, the net benefit to suppliers from perfect information would be 2F. That is, suppliers would benefit by twice the consumer loss from perfect information. Obversely, suppliers lose twice the consumer gain from perfect information. The net benefit to society from perfect information, i.e., the benefit

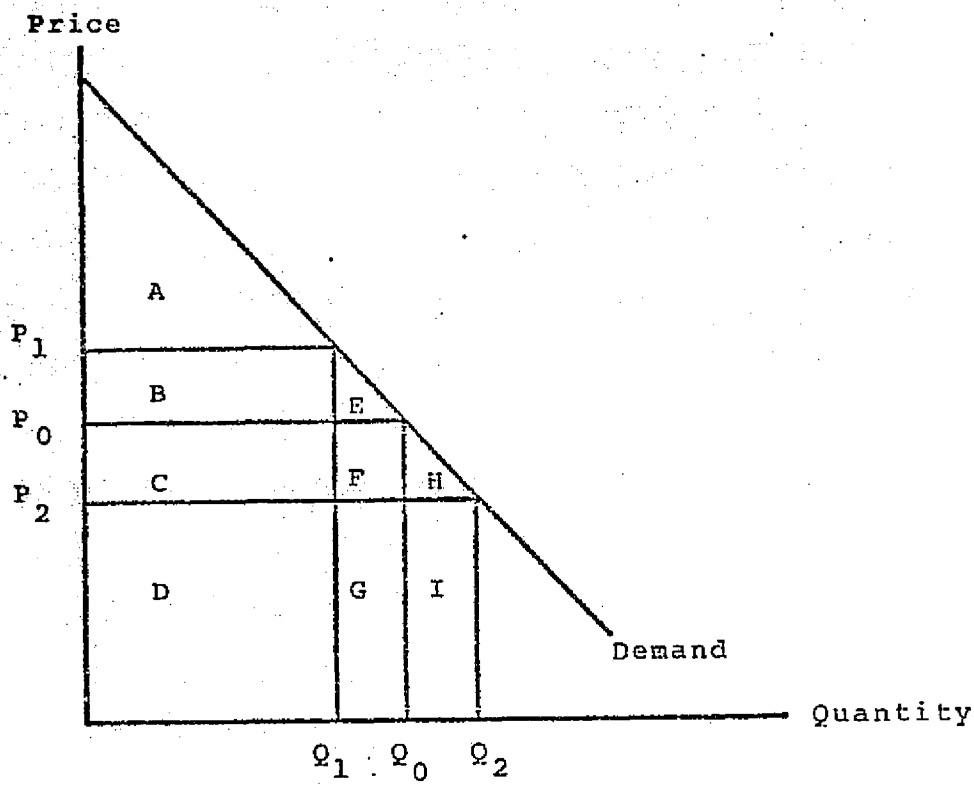

Figure 4.6 Consumer and Supplier Benefits

to consumers and producers taken together, would be 2F-F =F. Now it must be noted that the effect on consumers and suppliers may be quite different if either the demand linearity or symmetry assumptions are relaxed sufficiently. The case of symmetry is discussed below.

4.3.2 International Distribution Benefits: The Asymmetric Demand Case

Among the most serious shortcomings of the "linear symmetric" model is its behavioral symmetry with regard to over and underestimation errors. The conclusion that an exporting

country like the United States will lose from improved world crop forecasts rests on the assumption that societies offset first period abstinence or starvation by indulgence and gluttony in some future period. There are strong biological reasons supported by recorded actions that deny the validity of this assumption. Starvation in Biafra and Bangladesh was not "offset" by overconsumption in the period after their starvation. The obverse, of course, does not hold. That is, too high levels of imports in one period can be carried over, in part, to some future period. Under these conditions the benefits to an exporter such as the United States from improved world crop information take on a completely different character than suggested by the linear symmetric model. For an exporter, the trade and "surplus" effects would lead to net benefits from a reduction in crop forecast errors. This is shown in Figures 4.7 and 4.8. The first diagram, Figure 4.7, shows the two period effects of an underestimation error. As can be seen, the net impact of perfect information would be a loss of $\Delta P \cdot \Delta X = \alpha \Delta X^2$ to the exporter, where $\alpha = \Delta P/\Delta X$. In the second diagram, Figure 4.8, the effect of an overestimation error is shown. Here, perfect information would lead to net exporter benefits of $\Delta P\ [X_1 + \Delta X/2]$.

Assuming that over and underestimation errors are symmetrically distributed, the net effect to the exporter (the expected value) is that they stand to lose from misinformation

as long as the minimum level of exports X_1 exceeds the absolute value of the incremental change in exports owing to misinformation. In fact, the minimum level of exports need only 1/2 the size of the incremental change in exports. The net gain from misinformation in the underestimation case is equal to $\Delta P \cdot \Delta X$ and the net loss from misinformation in the overestimation case is equal to $\Delta P X_1 + \Delta P \Delta Q/2$. The expected net loss or potential benefit from perfect information is $\frac{\Delta P}{2} \, [X_1 + \Delta X/2] - \frac{\Delta P}{2}$ or $\frac{\Delta P}{2} \, [X_1 - \Delta X/2]$. For this to be positive, it is necessary that the minimum level of exports, X_1 be greater than half the estimation error, $\Delta X/2$.

4.3.3 International Production Benefits

A second major shortcoming of the linear symmetric world trade model is it does not allow for "producer" or "buffer stock" benefits. Here, improved crop forecasts for the exporting and importing country can lead to net benefits from both importers and exporters. These benefits and their impact on consumers and suppliers within each country (exporter and importer) are shown in Figure 4.9. In Figure 4.9 the benefits to importers and exporters are shown with regard to a supply efficiency in the exporting country owing to improved information. As can be seen, importers clearly benefit and exporters may also benefit depending on the exporters' elasticities of supply and demand and the relation to total supply to exports.

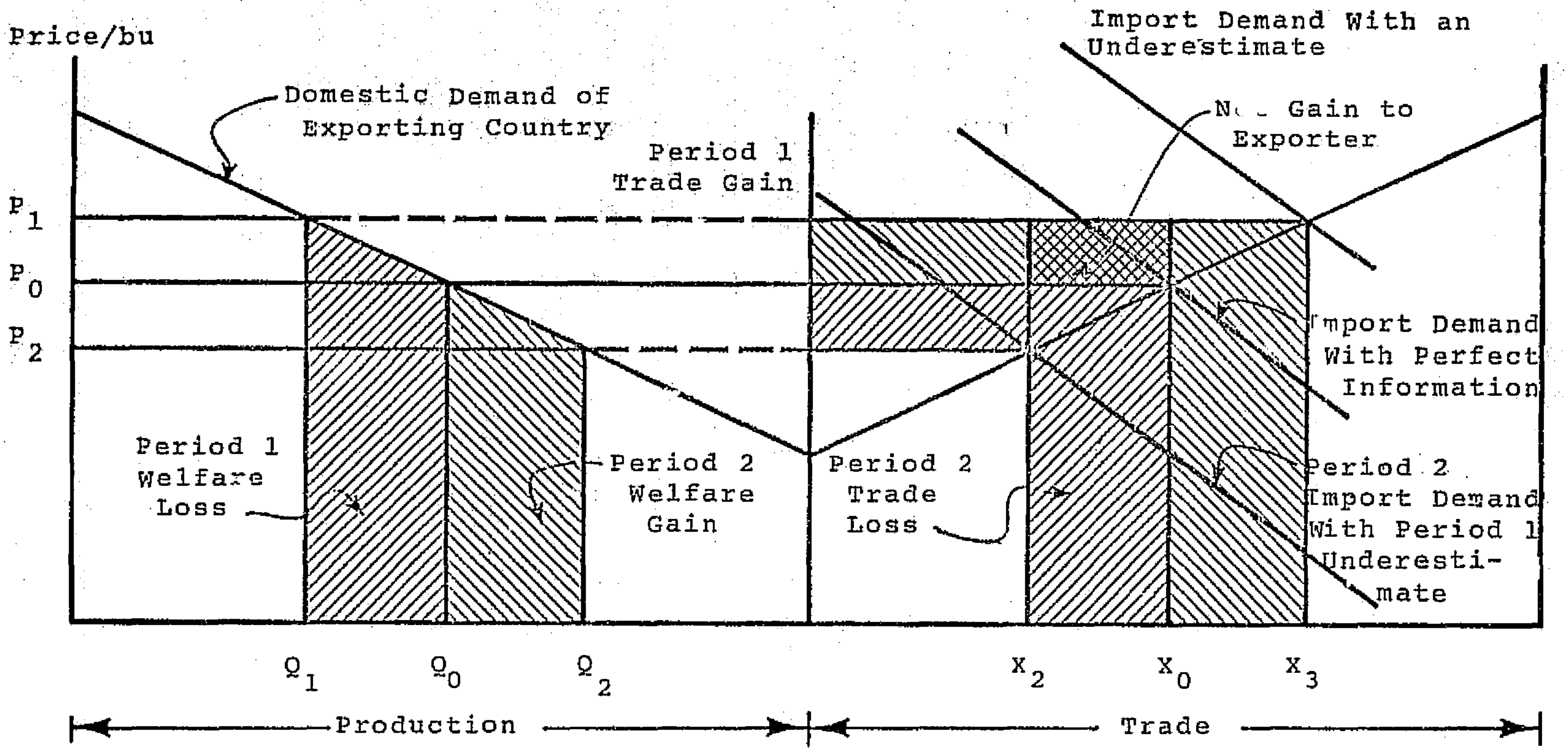

Figure 4.7 Two-period Gains and Losses to an Exporting Country From a First-period Underestimation of Supply in an Importing Country

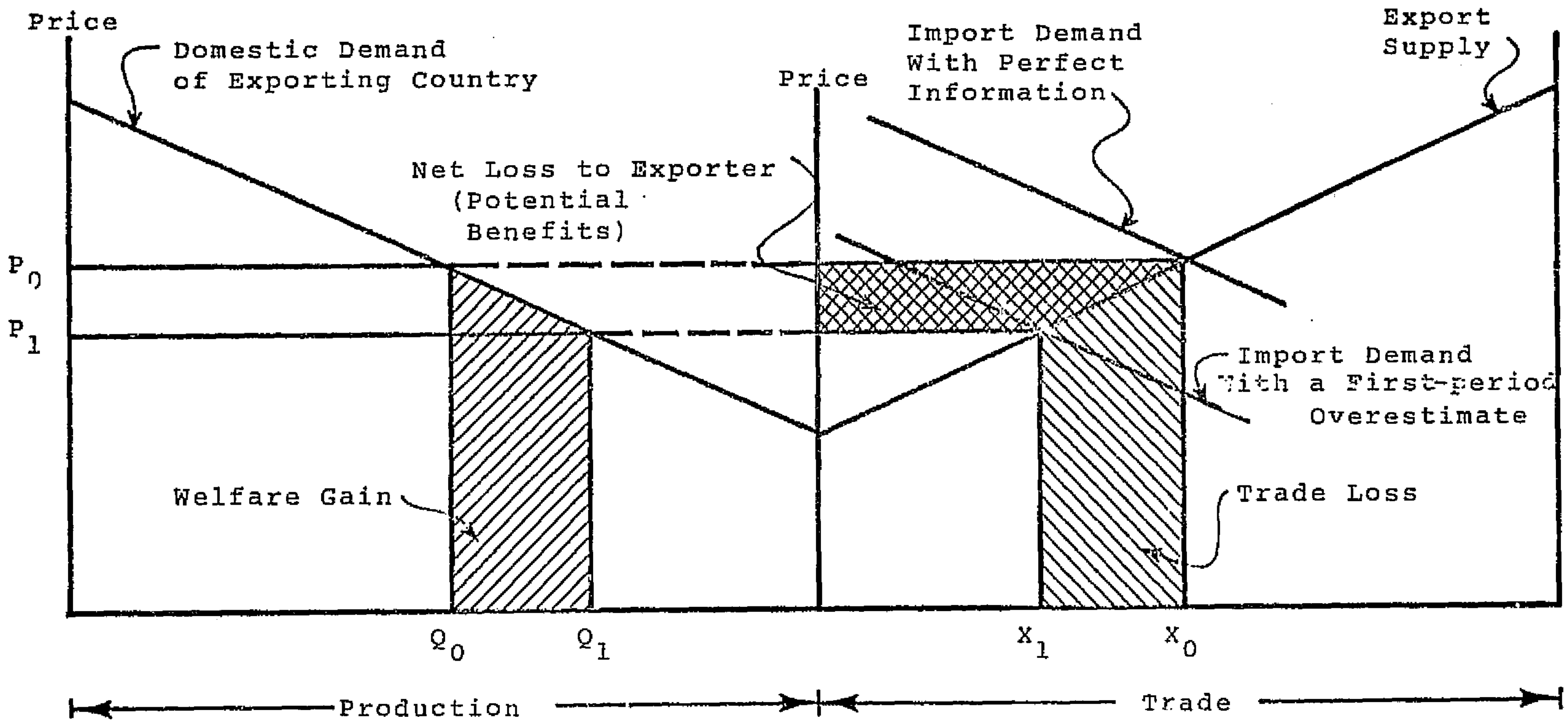

Figure 4.8 Two-period Gains and Losses to an Exporting Country From a First-period Overestimation of Supply in an Importing Country

The detailed calculation of the supply impact benefits to the exporter will reveal that, over time, there is in fact a net benefit to the United States from improved crop information through the supply effects postulated in this study.

4.4 The Benefits to the United States as Exporter

The analysis of the benefits to the United States falls into three distinct parts: (i) consumer benefits, (ii) producer benefits and (iii) net U.S. benefits.

4.4.1 For Consumers

In case the average period price is lower for the improved (P_I^*) then for the baseline (P_B^*) case, there is a gain represented in Figure 4.10 by area <abcd>. The calculation of this gain - or the corresponding loss if the price relationship is inverted - can be done for each of the 24 months over which the model has been implemented. The average annual benefit for consumers is then:

$$\Delta CS = \sum_{t=1}^{24} (CS_t^{\,I} - CS_t^{\,B})/2$$

$$\sum_{t=1}^{24} (P_{B,t}^* - P_{I,t}^*)\ (C_{B,t} + C_{I,t})/4$$

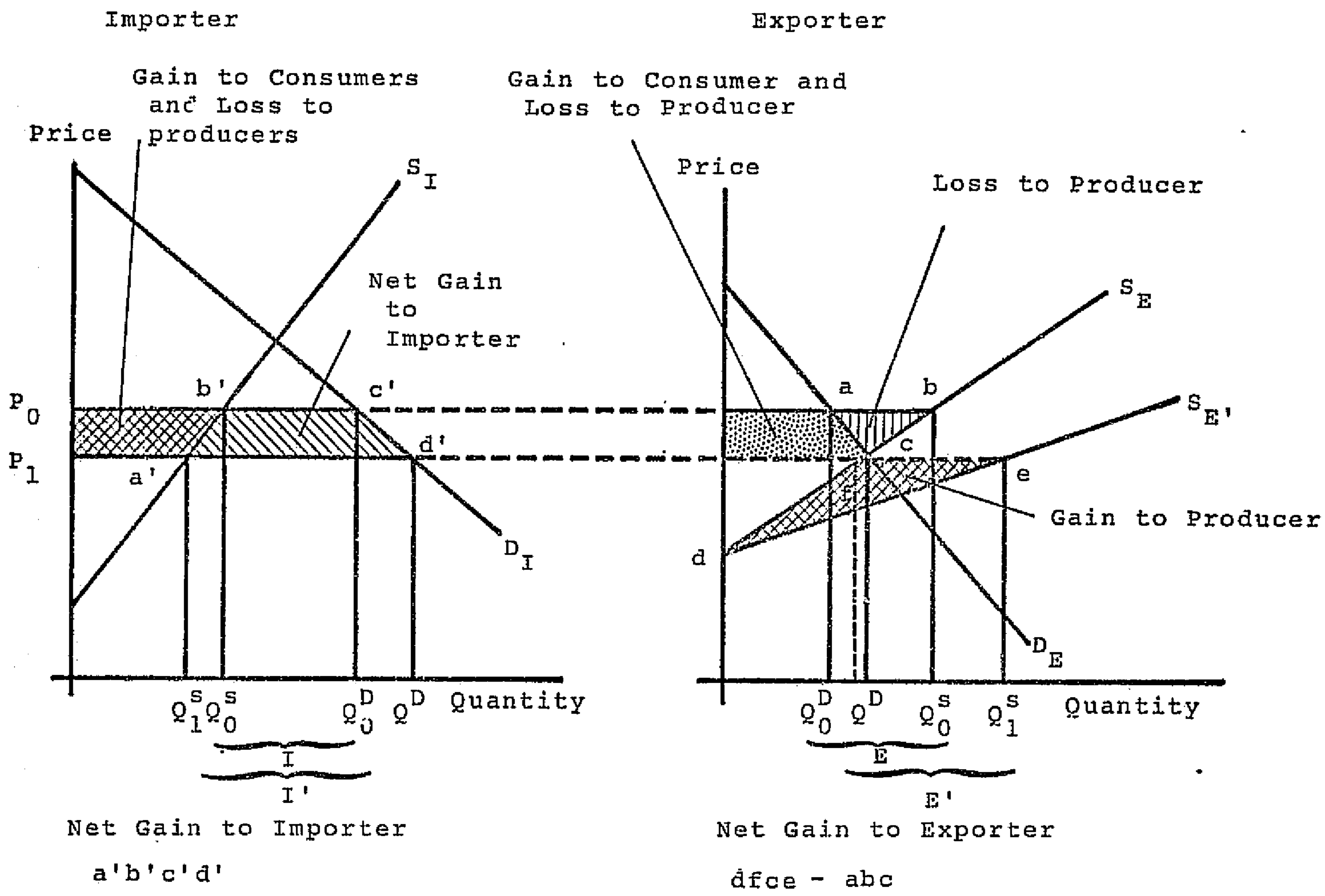

Figure 4.9 The Export Supply Impact of Improved Crop Information to Importers and Exporters

where

$P^*_{B,t}$ = Baseline Case equilibrium price in month t

$P^*_{I,t}$ = Improved Case equilibrium price in month t

$C_{B,t}$ = Baseline Case U.S. domestic consumption in month t

$C_{I,t}$ = Improved Case U.S. domestic consumption in month t

For a price change of opposite sign, the algebra is the same, reflecting a consumer loss. This method of averaging reflects the way in which price changes impact the consumers: there is a direct gain or loss in terms of the welfare measure employed here, i.e., consumer surplus. The alternative method, described below is preferrable if the results of the above calculation are not sufficiently stable over the time period of the modeled effects.

4.4.2 For Producers

There are two components of the static equilibrium analysis. Assuming a lower equilibrium average price as a result of the improved information, there are:

(i) "net efficiency gains" corresponding to the increased trade at the lower price, represented by (+) area <ifj> in Figure 4.10

(ii) "offset trade losses" due to the export price being lower over the baseline range of export quantities, represented by (-) area <abje> in Figure 4.10. This component, however, is not

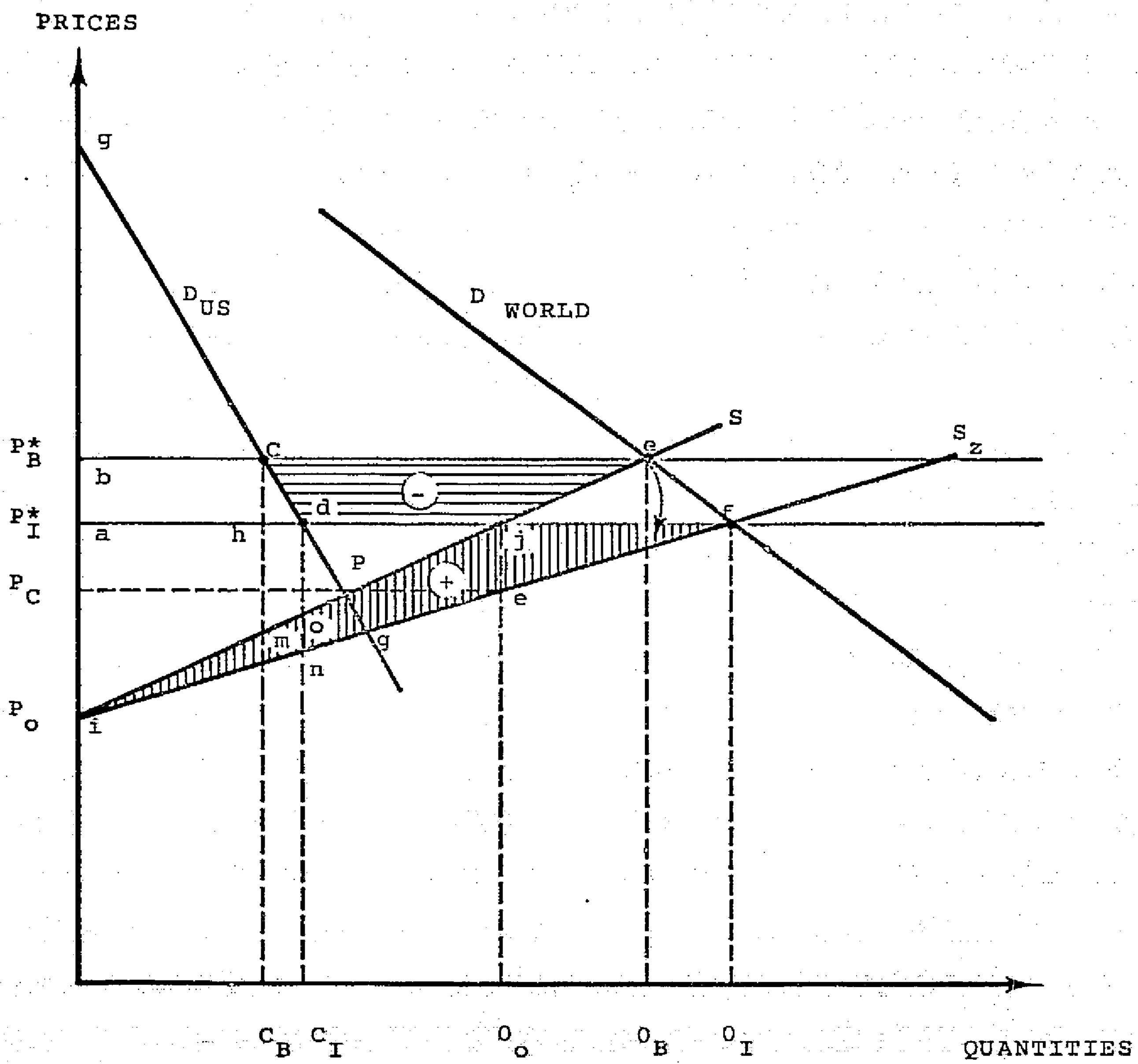

Figure 4.10 United States (Exporter) Benefits When There is a Downward Shift in the Marginal Cost-of-Supply Function

the entire international trade effect which will be treated separately below.

It is not meaningful to average these benefits in the same way as for the consumers because of the equilibrium analysis of the producer surplus can only be derived from a long-run downward shift in the marginal cost-of-supply function. We do not want to assume that the latter fluctuates from month to month to produce the observed or modeled prices and quantities. Accordingly, the average price in the improved case is compared with the average price in the baseline case to obtain a valid measure of the downward shift in supply costs. The calculations, expressed in the same terms as were used in 4.4.1, are as follows. Average equilibrium prices for baseline and improved cases are:

$$P_B^* = \sum_{t=1}^{24} P_{B,t}^*/24$$

$$P_I^* = \sum_{t=1}^{24} P_{I,t}^*/24$$

The average annual producer gains or losses are the algebraic sum of NEG and TOL given below: $\Delta PS = NEG + TOL$;

NEG = net efficiency gains = $(P_I^* - P_o)\ (\bar{Q}_I - \bar{Q}_o)\ /2$

TOL = trade offset losses = $-(P_B^* - P_I^*)\ (\bar{Q}_o + \bar{Q}_B - \bar{C}_B - \bar{C}_I)/2$

where P_o is the marginal cost of supplying the first ton of wheat

$$Q_o = ((P_I^* - P_o) / (P_B^* - P_o))\ Q_B$$

Q_B = baseline world supply, C_B = baseline U.S. consumption
Q_I = improved world supply, C_I = improved U.S. consumption
and the bar (as in $\overline{Q}_I$) denotes annual average.

4.4.3 Net Gains or Losses to the United States

With reference to Figure 4.10, it is clear that the mere algebraic combining of static consumer and producer gains and losses as described in 4.4.1 and 4.4.2 would result in a net value represented by area <ijf> - area <cdje>, since area <abcd> is included in consumer and producer benefits with opposite sign. For the dynamic case, however, there is a slight difference if we calculate benefits using the different types of averaging described for the consumer and producer benefit analyses. Nevertheless, the combined effect is similar to the one represented in Figure 4.10 by <ijf> - <cdje> as will easily be seen by consideration of the numerical results obtained with the computer model. The net U.S. benefits are calculated as the sum of ΔCS and ΔPS given in Section 4.4.1 and 4.4.2 above. The algebraic addition of the consumer and producer benefits leads to the net U.S. benefits. Of course if there are producer <u>losses</u> they are numerically subtracted from the consumer gains. Other benefits, such as the trade effects discussed in the next section, may not be added, since they represent different methods of subdividing the same total quantity.

4.4.4 Trade Benefits to the United States

Adopting a different point of view, there are potential gains for the U.S. from increased international trade which cannot be accounted for within the framework of Sections 4.4.1 - 4.4.3. The average price of exported U.S. wheat being lower in the improved case than the baseline case, these are conditional benefits, dependent on the strength of the world demand for U.S. wheat. We present the calculations for these potential benefits here as a matter of special interest, although they cannot be added to the consumer and producer benefits since that would amount to double counting. Defining

T_B = U.S. average annual exports of wheat in baseline case

T_I = U.S. average annual exports of wheat in improved case

The net U.S. trade benefits are:

$$(((P_I^* - P_O)/Q_I)T_I^2 - ((P_B^* - P_O)/Q_B)T_B^2)/2$$

corresponding to area <dnf> - area <cme> in Figure 4.10. These may be quite substantial, particularly if the average price drop is small but the volume of U.S. exports significantly expanded. They represent increased trade revenues to the U.S. even at the lower world price, as a result of improved wheat crop information on a worldwide basis. Of course, these benefits, unlike the consumer benefits, are conditional upon the U.S. remaining a major net exporter of wheat.

4.5 Estimated Long-term Benefits

Long-term net benefits to the U.S. and to the consumers and producers of the U.S. are presented in Table 4.1. As can be seen, long-term U.S. consumer benefits are about $287 million a year, assuming stable population and constant tastes. Under similar assumptions, long-term annual rest of world consumer benefits are likely to achieve a level of over $4.3 billion a year*. The U.S. producers show long-term supply side net efficiencies owing to improved crop information (reductions in risk). These gains amount to $280 million a year. At the same time, wheat prices are lower by about 10 cents per bushel on the average. When United States total production is considered, this price drop leads to producer "offset" losses of $394 million a year on the average. The combined effect is a net producers loss of about $113 million a year. Both the United States and the rest of world also reap net trade benefits. For the United States these are about $334 million a year. The net U.S. long-term annual benefits to the nation from a LANDSAT system with worldwide crop coverage are also listed in Table 4.1. They are a simple arithmetic sum of the benefits to consumers and producers, provided the trade benefits are not included separately (they have already been accounted for). For the United States,

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*Based on the ratio of rest of world consumption demand for wheat to U.S. demand.

Table 4.1 Average Annual Benefits to the United States From Improved Wheat Information (in millions of 1975 dollars)

Types of Benefit	Benefit
U.S. Consumers' Gains	287.69
U.S. Producers' Net Efficiency Gains	280.12
U.S. Producers' Offset Losses[1]	-393.78
Net Gains to U.S. Economy	174.03
Trade Gains for U.S. as Exporter Revenues[2]	333.91

[1] Due to the lower average prices, which apply to all production.

[2] Non-additive with the other benefits. Due to 26% increase in trade.

the total net benefits from these information improvements are about $174 million.

The benefits to consumers, increased production efficiencies, foreign trade and total benefits to the United States and the rest of world are calculated according to the methodology expressed in earlier sections of this chapter and using the results of the world wheat market model as described in Chapter 3.

It is important to note that the information improvements occur mostly in the rest of world: all economic effects in the United States and elsewhere reflect LANDSAT information improvements as reported in Chapter 2. Again, the information derived from LANDSAT data is assumed to be made available to all countries at this time, i.e., on a nondiscriminatory basis, similar to present practices of the Statistical Reporting Service of the USDA.

The results bear out some of our hypotheses and expectations expresed in Chapter 1. United States consumers benefit from public information improvements in the rest of world, wheat export trade benefits to the U.S. economy are positive and so are the net efficiency gains in the United States. These benefits all measure benefits to particular user groups and are not fully additive. In total, the United States gains from improved public information in free world trade. The rest of world might also gain from improved infor-

mation, although these effects cannot be quantified with the same precision as for United States at present. Of particular interest is that the trade gains of the United States economy are positive and so are the trade gains of the rest of world, confirming a rather old notion that both parties gain from trade, where here the gain to both parties is due to improved public information on worldwide crops.

The quoted annual benefits are the expected values from public information improvements of a LANDSAT type system. These have to be compared to the expected "annualized" cost of a three-satellite LANDSAT system of about $60 million. The benefit numbers are subject to further verification and are more sensitive to changes in economic and technical parameters than are the relatively certain costs. The long-term benefits listed herein may be realized by 1985 or 1990.

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UNITED STATES BENEFITS OF IMPROVED

WORLDWIDE WHEAT CROP INFORMATION

FROM A LANDSAT SYSTEM

APPENDICES

APPENDIX A

Wheat Forecast Source Data

and Statistical Summaries

Table A1 Historical Forecasts for the United States
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	30.4	33.0	36.7	37.1	37.2	37.2
1961	32.7	36.6	28.8	32.8	32.9	33.0
1962	33.9	28.8	28.6	28.9	29.8	29.8
1963	34.7	29.5	30.2	31.3	33.6	30.8
1964	33.0	33.0	34.7	35.0	35.1	35.0
1965	33.9	34.9	36.9	37.5	37.0	36.9
1966	38.2	33.6	33.8	35.0	35.3	35.3
1967	41.3	42.2	43.4	41.1	42.0	42.3
1968	36.3	33.5	43.2	43.7	43.5	43.5
1969	38.6	31.6	38.8	39.7	39.7	39.6
1970	39.5	29.3	36.7	36.9	37.0	37.0
1971	39.7	40.2	42.1	43.6	44.2	44.3
1972	41.4	42.1	42.2	42.0	42.4	42.4
1973	48.9	47.5	47.6	46.7	47.0	47.0
1974	59.1	55.9	52.4	51.6	48.8	48.5

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	37.2	37.1	37.1	37.1	37.1	37.1	36.9
1961	33.0	33.6	33.6	33.6	33.6	33.6	33.5
1962	29.8	29.7	29.7	29.7	29.7	29.7	29.7
1963	30.8	30.9	30.9	30.9	30.9	30.9	31.2
1964	35.0	35.1	35.1	35.1	35.1	35.1	34.9
1965	36.9	36.1	36.1	36.1	36.1	36.1	35.8
1966	35.3	35.7	35.7	35.7	35.7	35.7	35.5
1967	42.3	41.5	41.5	41.5	41.5	41.5	41.0
1968	43.5	42.7	42.7	42.7	42.7	42.7	42.4
1969	39.6	39.7	39.7	39.7	39.7	39.7	39.3
1970	37.0	37.5	37.5	37.5	37.5	37.5	36.8
1971	44.3	44.6	44.6	44.6	44.6	44.6	44.0
1972	42.4	42.1	42.1	42.1	42.1	42.1	42.1
1973	47.0	46.6	46.6	46.6	46.6	46.6	46.6
1974	48.5	48.8	48.8	48.8	48.8	48.8	48.8

Source: ECON calculations based on UK Grain Bulletin and FAO Production Yearbook data.

Table A2 Historical Forecasts for Argentina
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	9.0	[illegible]	9.0	9.0	9.0	9.0
1961	8.6	8.6	8.6	8.6	8.6	8.6
1962	8.2	6.2	[illegible]	7.3	7.0	7.0
1963	9.2	9.2	9.2	7.2	7.2	7.2
1964	8.7	8.7	8.7	8.7	8.7	8.7
1965	10.3	10.3	10.3	10.3	10.3	10.3
1966	11.0	11.0	11.0	11.0	11.0	11.0
1967	11.2	11.2	11.2	11.2	11.2	11.2
1968	11.6	11.6	11.6	11.6	11.6	11.6
1969	10.7	10.7	10.7	10.7	10.7	10.7
1970	9.4	9.4	9.4	9.4	9.4	9.4
1971	9.2	9.2	9.2	9.2	9.2	9.2
1972	8.9	8.9	8.9	8.9	8.9	8.9
1973	9.2	9.2	9.2	9.2	9.2	6.9
1974	9.3	9.3	9.3	10.2	11.2	11.2

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	9.0	9.0	5.9	5.7	5.7	5.7	5.7
1961	8.6	8.6	8.6	8.6	8.6	7.4	8.2
1962	7.0	6.4	6.9	7.0	7.0	7.0	8.2
1963	7.2	7.2	9.6	10.2	10.2	10.2	12.7
1964	8.7	8.7	10.9	13.2	13.2	13.2	16.2
1965	10.3	8.2	8.2	8.2	8.2	8.2	8.7
1966	11.0	9.3	9.3	9.3	9.6	9.6	8.9
1967	12.2	12.2	11.2	10.6	10.6	10.6	10.4
1968	11.6	11.6	11.6	8.4	8.4	8.4	8.2
1969	10.7	10.7	10.7	10.7	9.6	9.6	10.0
1970	9.4	9.4	6.0	6.1	6.0	6.0	7.0
1971	9.2	7.4	7.4	7.4	7.2	7.2	8.2
1972	8.9	8.9	8.9	11.6	11.6	11.6	11.3
1973	6.9	6.9	6.9	8.3	8.3	8.3	9.4
1974	11.2	11.2	8.4	8.4	8.4	8.4	10.0

Source: ECON calculations based on UK Grain Bulletin and FAO Production Yearbook data.

Table A3 Historical Forecasts for Australia (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	6.7	6.7	6.7	6.7	6.7	6.7
1961	7.3	7.3	7.3	7.3	7.3	7.3
1962	8.2	8.2	9.6	9.6	12.0	12.0
1963	9.9	9.9	9.9	12.0	12.0	12.0
1964	10.7	10.7	10.7	10.7	10.7	10.7
1965	12.0	12.0	12.0	12.0	12.0	12.0
1966	12.0	12.0	12.0	12.0	12.0	12.0
1967	13.7	13.7	13.7	13.7	13.7	13.7
1968	13.4	13.4	13.4	13.4	13.4	13.4
1969	15.2	15.2	15.2	15.2	15.2	15.2
1970	15.3	12.4	12.4	12.4	12.4	12.4
1971	15.6	15.6	15.6	15.6	15.6	15.6
1972	14.3	14.3	14.3	14.3	14.3	14.3
1973	20.2	20.2	20.2	14.6	14.6	17.4
1974	13.3	13.3	15.3	15.3	15.3	16.0

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	6.7	6.7	9.6	9.6	9.6	10.4	10.6
1961	7.3	7.3	7.3	7.3	7.3	9.6	9.6
1962	12.0	10.7	11.2	11.7	11.7	11.7	12.0
1963	11.2	11.2	11.4	12.6	12.6	12.6	12.7
1964	10.7	10.7	13.7	13.7	13.6	15.0	14.3
1965	12.0	12.0	9.9	9.9	9.7	9.7	10.2
1966	12.0	14.4	16.4	16.4	17.4	17.4	18.2
1967	13.7	13.7	10.2	10.7	10.7	10.9	10.7
1968	17.0	17.0	17.0	17.7	17.7	20.9	21.2
1969	15.2	15.2	15.2	16.0	16.0	16.0	15.0
1970	12.4	12.4	12.2	12.2	12.2	12.2	11.3
1971	15.6	15.6	15.6	12.0	12.0	12.0	12.2
1972	14.3	14.3	14.3	14.3	14.3	9.2	9.6
1973	17.4	17.4	17.4	16.4	16.4	16.4	17.2
1974	16.0	16.0	16.0	16.0	16.0	16.0	15.7

Source: ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.

Table A4 Historical Forecasts for Canada
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	18.4	18.4	18.4	18.4	18.4	18.4
1961	18.4	18.4	18.4	18.4	9.9	10.2
1962	16.2	16.2	16.2	16.2	21.7	21.5
1963	17.6	17.6	17.6	17.6	27.0	28.0
1964	20.2	20.2	20.2	20.2	23.3	23.3
1965	21.3	21.3	21.3	21.3	29.6	27.5
1966	22.3	22.3	22.3	22.3	31.2	32.7
1967	26.7	26.7	26.7	26.7	21.3	23.2
1968	26.9	26.9	26.9	26.9	25.3	24.5
1969	26.3	26.3	26.3	26.3	26.5	26.7
1970	27.0	27.0	27.0	27.0	13.2	12.9
1971	24.5	24.5	24.5	24.5	19.7	20.3
1972	22.2	22.2	22.2	22.2	22.2	20.6
1973	27.6	27.6	27.6	27.6	27.6	24.3
1974	21.3	21.3	21.3	23.3	20.6	20.6

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	18.4	18.4	19.2	19.2	19.2	19.2	20.2
1961	10.2	10.2	10.2	10.2	10.2	10.2	11.0
1962	21.5	21.7	21.7	21.7	21.7	21.7	22.0
1963	28.2	28.2	28.2	28.2	28.2	28.2	28.2
1964	23.3	23.3	23.3	23.3	23.5	23.5	23.3
1965	27.5	27.5	26.5	26.5	26.5	26.3	25.0
1966	32.7	32.7	32.7	32.7	32.9	32.9	31.2
1967	23.2	23.2	23.2	23.2	23.2	23.2	23.0
1968	24.5	24.5	24.5	25.3	25.3	25.3	25.3
1969	26.7	26.7	26.7	26.7	26.7	26.7	26.6
1970	12.9	12.9	12.9	12.9	12.9	12.9	12.9
1971	20.3	20.4	20.4	20.4	20.4	20.4	20.6
1972	20.6	20.7	20.7	20.7	20.7	20.7	20.7
1973	24.3	24.5	24.5	24.5	24.5	24.5	23.6
1974	20.4	20.4	20.4	20.4	20.4	20.4	20.4

Source: **ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.**

Table A5 Historical Forecasts for France
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	14.0	14.0	14.0	14.0	14.0	14.0
1961	14.3	14.3	14.7	13.7	13.4	13.3
1962	15.4	15.4	16.0	16.0	19.9	18.9
1963	16.3	16.3	16.3	13.2	13.3	13.0
1964	16.4	16.4	16.4	19.4	19.2	19.2
1965	17.2	17.2	20.0	20.4	20.2	20.2
1966	18.2	18.2	18.0	18.0	17.6	16.3
1967	12.4	12.4	18.3	18.3	18.9	20.3
1968	18.7	18.7	18.7	18.7	20.9	20.9
1969	20.2	20.2	20.2	20.2	20.4	20.3
1970	20.3	20.3	20.3	20.3	18.6	18.3
1971	19.7	19.7	19.7	19.7	21.6	21.6
1972	21.9	21.9	22.0	22.0	23.0	25.3
1973	22.2	22.2	22.2	25.3	25.3	25.3
1974	25.5	25.5	25.5	25.0	26.2	27.0

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	14.0	14.0	15.6	15.6	15.6	15.6	15.7
1961	13.3	13.3	13.3	13.3	13.3	13.4	13.7
1962	19.9	19.9	19.9	19.9	19.9	19.9	20.2
1963	13.0	13.7	13.7	13.7	13.7	13.7	14.6
1964	19.2	19.2	19.2	19.2	19.4	19.4	19.7
1965	20.6	20.6	20.6	20.6	20.6	20.6	21.2
1966	16.3	16.2	16.3	16.2	16.2	16.2	16.2
1967	20.2	20.7	20.6	20.6	20.6	20.6	20.4
1968	21.3	21.3	21.3	21.3	21.3	21.3	21.5
1969	20.[illegible]	20.9	20.9	20.9	20.9	20.9	20.7
1970	18.3	18.4	18.4	18.4	18.4	18.4	18.4
1971	21.6	22.0	22.0	22.0	22.0	22.0	22.2
1972	25.3	25.3	25.3	25.3	25.2	25.3	25.3
1973	25.3	25.6	25.6	25.5	25.5	25.5	25.5
1974	27.0	27.0	27.0	27.0	27.0	27.0	27.0

Source: ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.

Table A6 Historical Forecasts for India (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	13.2	13.2	13.2	13.2	13.2	13.2
1961	13.6	13.6	13.6	15.4	15.4	15.4
1962	14.2	14.2	15.4	15.4	16.9	16.9
1963	15.0	15.0	12.3	16.9	16.9	16.9
1964	15.7	15.7	15.7	13.9	13.9	13.9
1965	15.7	15.7	15.7	15.7	15.7	17.3
1966	16.4	16.4	16.4	16.4	16.4	16.4
1967	16.2	16.2	16.2	16.2	16.2	16.2
1968	15.9	15.9	15.9	15.9	23.7	23.7
1969	17.6	24.7	24.7	24.7	24.7	24.7
1970	20.2	20.2	20.2	20.2	28.7	28.7
1971	22.5	22.5	22.5	22.5	33.3	33.3
1972	26.3	26.3	26.3	26.3	35.9	35.9
1973	30.7	30.7	30.7	30.7	30.7	30.7
1974	35.8	35.8	35.8	35.8	35.8	35.8

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	13.2	13.2	13.2	13.2	13.2	13.2	14.7
1961	15.4	15.4	15.4	15.4	15.4	15.4	15.7
1962	16.9	16.9	16.9	16.9	16.9	16.9	17.3
1963	16.0	15.9	15.9	16.0	16.0	16.0	15.4
1964	13.9	13.9	13.9	13.9	13.9	13.9	14.2
1965	17.3	17.3	17.3	17.3	17.3	17.3	17.6
1966	16.4	16.4	16.4	15.3	15.3	15.3	14.9
1967	16.2	16.2	16.7	16.6	16.6	16.6	16.3
1968	23.7	23.7	23.7	23.7	23.7	23.7	23.6
1969	24.7	26.7	26.7	26.7	26.7	26.7	26.7
1970	28.7	28.7	28.7	28.7	28.7	28.7	28.7
1971	33.3	33.3	33.3	33.3	33.3	33.3	34.0
1972	35.9	35.8	36.6	37.9	37.9	37.9	37.8
1973	30.7	30.7	30.7	30.7	30.7	30.7	35.6
1974	35.8	35.8	31.6	31.6	31.6	31.6	32.9

Source: ECON calculations based on UK _Grain Bulletin_ and FAO _Production Yearbook_ data.

Table A7 Historical Forecasts for Italy
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	13.2	13.2	13.2	13.2	13.2	13.2
1961	12.3	12.3	12.3	12.3	11.3	11.3
1962	12.2	12.2	12.2	12.2	12.2	13.2
1963	12.4	12.4	12.4	11.9	11.9	11.9
1964	12.0	12.0	12.0	13.2	12.9	12.9
1965	12.0	12.0	12.7	13.6	13.6	13.6
1966	12.9	12.9	13.7	13.2	13.2	13.2
1967	13.2	13.2	12.6	12.6	13.0	13.0
1968	13.3	13.3	13.3	13.3	13.4	13.4
1969	13.7	13.7	13.7	13.7	13.7	13.7
1970	14.0	14.0	14.0	14.0	14.0	13.7
1971	14.0	14.0	14.0	14.0	14.0	14.2
1972	14.2	14.2	14.2	13.6	13.6	13.6
1973	14.0	14.0	14.0	12.7	12.7	12.7
1974	12.7	12.7	12.7	13.9	13.9	13.7

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	13.2	13.2	9.7	9.7	9.7	9.7	9.7
1961	11.3	11.3	11.3	11.3	11.3	11.9	11.9
1962	13.2	13.2	13.7	13.6	13.6	13.6	13.6
1963	11.6	11.6	11.6	11.6	11.6	11.6	11.6
1964	12.9	12.9	12.9	12.9	12.3	12.3	12.3
1965	13.7	14.0	14.0	14.0	14.0	14.0	14.0
1966	13.2	13.2	13.2	13.4	13.4	13.4	13.4
1967	13.0	13.0	13.7	13.7	13.7	13.7	13.7
1968	13.4	13.4	13.4	13.7	13.7	13.7	13.9
1969	13.7	13.7	13.7	13.7	13.7	13.7	13.7
1970	13.7	13.7	13.9	13.9	13.9	13.9	13.9
1971	14.2	14.2	14.2	14.2	14.4	14.4	14.3
1972	13.6	13.4	13.6	13.6	13.6	13.4	13.4
1973	12.7	12.7	12.7	12.9	12.9	12.9	12.7
1974	13.7	13.7	13.7	13.7	13.7	13.7	13.7

Source: ECON calculations based on UK Grain Bulletin and FAO Production Yearbook data.

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Table A8 Historical Forecasts for the Republic of South Africa (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	1.1	1.1	1.1	1.1	1.1	1.1
1961	1.1	1.1	1.1	1.1	1.1	1.1
1962	1.1	1.1	1.1	1.1	1.1	1.1
1963	1.1	1.1	1.1	1.1	1.1	1.1
1964	1.1	1.1	1.1	1.1	1.1	1.1
1965	1.3	1.3	1.3	1.3	1.3	1.3
1966	1.3	1.3	1.3	1.3	1.3	1.3
1967	1.1	1.1	1.1	1.1	1.1	1.1
1968	1.3	1.3	1.3	1.3	1.3	1.3
1969	1.4	1.4	1.4	1.4	1.4	1.4
1970	1.4	1.4	1.4	1.4	1.4	1.4
1971	1.7	1.7	1.7	1.7	1.7	1.7
1972	2.0	2.0	2.0	2.0	2.0	2.0
1973	2.1	2.1	2.1	2.1	2.1	2.1
1974	2.3	2.3	2.3	2.3	2.3	2.3

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	1.1	1.1	1.1	1.0	1.0	1.0	1.1
1961	1.1	1.1	1.1	1.1	1.1	1.1	1.3
1962	1.1	1.1	1.0	1.0	1.0	1.0	1.0
1963	1.1	1.1	1.1	1.1	1.1	1.1	1.3
1964	1.1	1.1	1.1	1.1	1.1	1.1	1.6
1965	1.3	1.3	1.3	1.3	1.0	1.0	1.0
1966	0.9	0.9	0.9	0.9	0.9	0.9	0.9
1967	1.1	1.1	1.1	1.1	1.1	1.1	1.6
1968	1.3	1.3	1.3	1.7	1.7	1.7	1.9
1969	1.4	1.7	1.7	1.7	1.9	1.9	1.9
1970	1.4	1.7	1.7	2.0	2.0	2.0	2.0
1971	1.7	1.7	1.7	2.3	2.3	2.3	2.4
1972	2.0	2.6	2.6	2.6	2.6	2.6	2.4
1973	2.1	2.3	2.3	2.4	2.4	2.4	2.6
1974	2.3	2.3	2.1	2.1	2.1	2.1	2.6

Source: ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.

Table A9 Historical Forecasts for Spain (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	5.0
1961	6.3	6.3	6.3	6.3	4.7	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.9
1962	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	7.0	7.0	6.9
1963	6.1	6.1	6.3	6.4	6.4	6.4	6.4	7.0	7.0	7.0	7.0	7.0	7.6
1964	6.3	6.3	6.3	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.7	5.7	7.0
1965	6.4	6.4	6.3	6.0	6.0	6.0	6.0	6.0	6.3	6.3	6.3	5.9	5.7
1966	6.6	6.6	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.7
1967	6.9	7.3	7.3	7.3	7.7	7.6	8.0	8.0	8.0	8.0	8.0	8.0	7.0
1968	6.9	6.9	6.9	6.9	7.9	7.9	7.9	7.9	7.9	8.2	8.2	8.2	8.2
1969	7.0	7.0	7.0	7.0	7.6	7.0	6.7	6.7	6.7	6.7	6.7	6.7	6.6
1970	7.0	5.7	5.7	5.7	5.7	5.7	5.3	5.3	5.3	5.3	5.3	5.3	5.5
1971	7.0	7.0	7.0	7.0	7.4	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.9
1972	7.2	7.2	7.2	7.2	6.6	6.4	6.4	6.4	6.4	6.6	6.6	6.6	6.6
1973	7.2	7.2	7.2	7.2	7.2	7.2	7.2	5.9	5.9	5.6	5.6	5.6	5.6
1974	5.6	5.6	5.6	5.6	6.7	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4

Source: ECON calculations based on UK Grain Bulletin and FAO Production Yearbook data.

Table A10 Historical Forecasts for the United Kingdom (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	4.0	4.0	4.0	4.0	4.0	4.0
1961	4.1	4.1	4.1	4.1	5.4	3.4
1962	4.0	4.0	3.7	3.7	5.3	4.9
1963	4.4	4.4	4.4	5.3	4.0	4.0
1964	4.6	4.6	4.6	4.6	4.9	4.9
1965	4.9	4.9	4.9	5.7	5.6	5.6
1966	5.1	3.1	3.1	5.1	5.0	5.0
1967	1.9	1.9	1.9	1.9	5.6	5.4
1968	5.3	5.3	5.3	5.3	5.3	5.3
1969	5.4	5.4	5.4	5.4	5.4	5.4
1970	5.3	5.3	5.3	5.3	5.3	5.3
1971	5.4	5.4	5.4	5.4	5.4	5.4
1972	5.7	6.9	6.9	6.9	6.9	6.9
1973	6.0	6.0	6.0	7.0	7.0	7.0
1974	7.2	7.2	7.2	7.7	8.3	8.0

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	4.0	4.0	4.0	4.3	4.3	4.3	4.3
1961	3.4	3.4	3.4	3.4	3.4	3.7	3.7
1962	4.9	5.1	5.1	5.3	5.3	5.3	5.7
1963	3.9	3.7	3.7	4.4	4.4	4.4	4.3
1964	4.9	4.9	4.9	4.9	5.3	5.3	5.4
1965	5.6	5.6	6.0	6.0	6.0	6.0	6.0
1966	5.0	5.0	5.0	5.1	5.1	5.1	5.0
1967	5.6	5.6	5.6	5.6	5.6	5.6	5.6
1968	5.3	5.3	5.3	5.3	5.3	5.3	5.0
1969	5.4	5.4	5.4	4.9	4.9	4.9	4.9
1970	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1971	5.4	5.4	5.4	6.9	6.9	6.9	6.9
1972	6.9	6.9	6.9	6.9	6.9	6.9	6.9
1973	7.0	7.2	7.2	7.2	7.2	7.2	7.2
1974	8.0	8.0	8.7	8.7	8.7	8.7	8.3

Source: ECON calculations based on UK *Grain Bulletin* and FAO *Production Yearbook* data.

Table A11 Historical Forecasts for the U.S.S.R.
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	92.7	92.7	92.7	92.7	92.7	92.7
1961	97.7	97.7	97.7	97.7	97.7	97.7
1962	97.4	97.4	100.8	100.8	100.8	100.8
1963	101.1	101.1	101.1	101.1	101.1	101.1
1964	93.2	93.2	93.2	93.2	93.2	93.2
1965	94.8	94.8	94.8	94.8	94.9	94.8
1966	93.5	93.5	93.5	93.5	93.5	93.5
1967	103.4	103.4	103.4	103.4	103.4	103.4
1968	105.4	105.4	105.4	105.4	105.4	105.4
1969	118.1	118.1	118.1	118.1	118.1	118.1
1970	119.7	119.7	119.7	119.7	119.7	119.7
1971	131.3	131.3	131.3	131.3	131.3	131.3
1972	130.8	130.8	130.8	130.8	130.8	130.8
1973	133.3	133.3	136.1	136.1	136.1	136.1
1974	138.0	138.0	138.0	145.6	145.6	134.7
	NOV	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**FINAL**
1960	92.7	92.7	92.7	92.7	92.7	92.7	91.9
1961	97.7	97.7	97.7	97.7	97.7	97.7	95.1
1962	100.8	100.8	100.8	100.8	100.8	100.8	100.8
1963	101.1	101.1	101.1	101.1	101.1	101.1	71.1
1964	93.2	93.2	93.2	93.2	93.2	93.2	106.4
1965	94.8	94.8	94.8	94.8	84.4	82.9	85.4
1966	93.5	93.5	93.5	93.5	93.5	145.6	143.7
1967	118.0	118.0	118.0	118.0	118.0	118.0	110.7
1968	105.4	105.4	105.4	105.4	105.4	105.4	133.6
1969	118.1	118.1	118.1	118.1	118.1	118.1	114.1
1970	119.7	134.7	134.7	134.7	134.7	134.7	142.6
1971	131.3	131.3	131.3	131.3	131.3	131.3	141.3
1972	130.8	130.8	130.8	130.8	130.8	130.8	123.0
1973	136.1	155.7	155.7	155.7	155.7	155.7	156.9
1974	134.7	134.7	134.7	134.7	134.7	134.7	135.9

Source: ECON calculations based on UK *Grain Bulletin* and FAO *Production Yearbook* data.

Table A12 Simulated Forecasts for the United States (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	34.5	37.0	36.7	37.1	37.2	37.1
1961	33.9	33.4	33.4	32.8	32.9	33.2
1962	29.3	29.7	29.1	30.3	29.8	29.8
1963	31.4	31.7	31.0	31.3	31.0	30.8
1964	33.7	36.1	34.7	35.0	35.1	35.0
1965	35.2	34.9	35.3	36.8	35.2	36.9
1966	35.7	35.1	35.8	35.0	35.3	35.6
1967	41.3	42.2	41.1	41.1	42.0	41.9
1968	44.0	42.0	43.2	42.8	43.5	42.0
1969	38.6	39.2	38.8	39.7	39.7	39.6
1970	39.5	34.8	36.7	36.9	37.0	37.0
1971	46.3	41.7	44.3	43.9	44.2	44.0
1972	42.4	42.1	42.2	42.0	42.4	42.4
1973	47.5	47.4	45.1	46.5	47.0	46.4
1974	50.8	48.2	50.1	48.8	48.8	48.5

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	37.2	37.1	37.1	37.1	37.0	36.7	36.9
1961	33.4	33.6	33.6	33.6	33.6	33.6	33.5
1962	29.8	29.7	29.7	29.7	29.7	29.7	29.7
1963	30.8	30.9	31.4	31.1	31.1	30.9	31.2
1964	35.0	35.1	35.1	35.1	34.9	34.9	34.9
1965	35.0	36.1	35.6	36.1	35.8	36.0	35.8
1966	35.4	35.7	35.7	35.7	35.7	35.4	35.5
1967	42.1	41.4	40.9	41.0	41.5	41.5	41.0
1968	42.3	42.7	42.5	42.7	42.7	42.7	42.4
1969	39.6	39.7	39.7	39.7	39.7	39.7	39.3
1970	37.0	36.8	36.4	37.2	36.9	36.5	36.8
1971	44.3	44.6	44.2	44.6	44.1	44.1	44.0
1972	42.0	42.1	42.1	42.1	42.1	42.1	42.1
1973	47.0	46.6	46.6	46.6	46.6	46.6	46.6
1974	48.9	48.8	48.8	48.8	48.8	48.8	48.8

Source: ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.

Table A13 Simulated Forecasts for Argentina
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	5.5	6.0	5.7	5.6	5.7	5.7
1961	8.0	8.0	7.8	7.9	8.0	8.3
1962	8.2	8.2	7.9	8.5	8.2	8.2
1963	12.7	13.2	13.1	12.7	13.0	12.8
1964	17.1	15.8	16.4	16.0	15.9	16.1
1965	8.7	8.5	8.9	8.8	9.1	8.6
1966	8.7	8.9	9.3	8.8	9.1	9.1
1967	10.7	10.6	10.5	10.1	9.8	10.5
1968	8.5	8.2	8.1	8.2	7.9	8.2
1969	10.0	10.3	10.5	10.2	10.3	9.9
1970	7.0	7.0	7.0	7.1	7.4	7.3
1971	8.6	8.2	8.5	8.3	8.0	8.3
1972	11.1	11.2	11.8	11.5	11.4	11.5
1973	9.2	9.3	9.2	9.3	9.4	9.2
1974	10.1	10.5	10.3	10.2	9.8	9.8

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	5.8	5.8	5.6	5.7	5.7	5.7	5.7
1961	9.2	8.0	8.3	8.2	7.9	8.2	8.2
1962	8.3	8.2	9.3	8.1	8.0	8.2	8.2
1963	12.9	12.5	12.6	12.9	12.9	12.8	12.7
1964	16.9	15.6	16.5	15.9	16.2	16.3	16.2
1965	8.8	8.8	8.6	8.8	8.9	8.6	8.7
1966	8.8	8.8	9.0	8.6	8.9	8.9	8.9
1967	10.5	10.6	10.4	10.6	10.6	10.4	10.4
1968	8.2	7.9	8.1	8.4	8.1	8.1	8.2
1969	9.9	10.2	10.2	10.0	10.0	10.0	10.0
1970	6.9	6.8	6.9	6.9	7.0	7.0	7.0
1971	8.3	7.9	8.2	7.9	8.1	8.2	8.2
1972	11.2	11.2	11.2	11.3	11.1	11.1	11.3
1973	9.8	9.5	9.2	9.5	9.5	9.5	9.4
1974	10.1	10.1	9.9	10.2	10.1	10.3	10.0

Source: ECON calculations based on UK Grain Bulletin and FAO Production Yearbook data.

Table A14 Simulated Forecasts for Australia (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT.	OCT	
1960	10.4	10.5	10.4	10.8	10.1	10.9	
1961	9.1	9.3	9.4	10.1	9.9	9.7	
1962	12.0	12.9	11.4	12.3	12.0	12.0	
1963	13.0	13.1	12.6	12.5	12.9	13.0	
1964	13.8	13.8	14.2	15.1	14.5	14.4	
1965	10.2	10.1	10.1	10.7	10.4	10.2	
1966	18.3	17.9	18.6	17.4	17.8	18.3	
1967	10.8	10.9	11.1	10.8	10.7	10.8	
1968	21.6	22.2	20.7	21.8	21.5	20.7	
1969	15.1	15.2	14.9	15.2	15.1	15.0	
1970	10.9	11.8	11.3	11.2	11.2	11.7	
1971	12.8	13.2	12.2	12.2	11.9	12.9	
1972	9.6	9.7	9.6	9.4	9.7	9.5	
1973	16.8	16.9	17.0	16.8	17.2	17.4	
1974	15.1	15.9	15.6	15.6	15.3	15.5	
	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	10.6	10.4	10.6	10.7	10.7	10.5	10.6
1961	9.8	9.8	9.5	9.4	9.8	9.6	9.6
1962	12.0	12.1	12.1	11.8	12.2	11.9	12.0
1963	12.9	12.6	13.2	12.6	12.6	12.6	12.7
1964	14.2	14.1	14.5	13.9	14.7	14.3	14.3
1965	9.9	9.9	10.1	10.1	10.3	10.2	10.2
1966	17.6	18.5	18.2	17.7	18.2	18.2	18.2
1967	10.8	10.8	11.3	10.7	10.7	10.7	10.7
1968	20.8	22.1	21.2	21.1	21.1	21.2	21.2
1969	15.2	15.2	15.2	14.7	15.3	15.3	15.0
1970	11.1	11.4	11.2	11.3	11.2	11.2	11.3
1971	12.3	12.1	12.3	12.0	12.0	12.2	12.2
1972	9.9	9.5	9.5	9.4	9.6	9.6	9.6
1973	17.4	17.3	17.2	17.6	17.1	16.9	17.2
1974	15.0	16.0	15.9	15.8	16.0	15.9	15.7

Source: ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.

Table A15 Simulated Forecasts for Canada (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	20.2	19.8	20.0	20.7	20.9	20.6
1961	11.0	11.2	11.6	10.9	11.3	11.0
1962	22.9	23.3	21.8	22.4	22.2	21.5
1963	29.2	29.4	29.1	28.0	27.0	28.0
1964	22.3	23.1	22.7	23.8	23.3	23.3
1965	26.2	25.0	25.4	24.9	25.3	25.7
1966	30.8	32.8	32.0	33.5	31.2	32.7
1967	23.0	21.8	23.4	23.5	23.3	23.2
1968	25.3	26.0	25.2	25.1	25.3	25.7
1969	26.3	26.8	26.9	26.3	26.5	26.7
1970	12.9	13.2	12.9	12.7	13.2	12.9
1971	20.1	20.8	20.4	20.6	20.6	20.4
1972	21.0	20.7	20.6	21.5	21.3	20.6
1973	24.4	23.2	24.1	23.8	23.6	23.8
1974	19.8	20.1	20.9	19.7	20.6	20.6

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	20.7	21.0	20.2	19.8	20.1	20.1	20.2
1961	11.5	11.1	11.1	10.9	10.8	11.0	11.0
1962	22.2	21.8	22.0	21.7	22.0	22.3	22.0
1963	28.2	28.2	28.2	28.2	28.2	28.2	28.2
1964	23.3	23.3	23.3	23.3	23.5	23.5	23.3
1965	26.0	26.1	25.2	25.4	24.7	25.4	25.3
1966	32.7	32.7	32.7	32.7	31.9	32.4	32.2
1967	23.2	23.2	23.2	23.2	23.0	23.1	23.0
1968	24.7	25.7	26.0	25.3	25.3	25.3	25.3
1969	26.7	26.7	26.5	26.7	26.7	26.5	26.6
1970	12.9	12.9	12.9	12.9	12.9	12.9	12.9
1971	20.3	20.4	20.7	20.4	20.4	20.4	20.6
1972	20.6	20.7	20.7	20.7	20.7	20.7	20.7
1973	23.6	23.6	24.2	23.9	23.4	23.7	23.6
1974	20.4	20.4	20.4	20.4	20.4	20.4	20.4

Source: ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.

Table A16 Simulated Forecasts for France
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	15.5	16.9	16.0	15.6	15.6	15.6
1961	14.0	13.8	13.7	13.7	13.7	13.6
1962	19.8	20.6	19.1	20.8	19.9	19.0
1963	15.1	14.9	14.5	14.9	14.3	14.5
1964	20.2	19.8	19.8	19.7	19.5	19.4
1965	20.8	22.2	21.7	21.7	22.0	20.6
1966	16.2	16.1	16.4	16.0	16.7	16.3
1967	19.7	21.0	20.6	21.1	20.7	20.3
1968	21.0	21.1	21.7	20.0	21.3	20.9
1969	21.0	20.2	20.2	20.4	20.5	20.4
1970	18.4	19.0	18.9	18.4	18.3	18.3
1971	20.6	22.9	21.2	21.2	21.6	21.6
1972	26.5	26.2	26.3	25.0	26.9	25.8
1973	25.6	24.5	25.5	25.3	25.3	25.3
1974	27.0	26.2	25.8	27.3	27.7	27.0

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	15.8	15.5	15.7	15.6	15.6	15.6	15.7
1961	13.6	13.3	13.9	14.1	14.1	13.6	13.7
1962	20.6	20.2	20.2	20.0	20.1	20.4	20.2
1963	14.9	14.4	14.3	14.6	14.5	14.8	14.6
1964	19.2	19.6	19.5	19.6	19.5	19.7	19.7
1965	21.4	20.8	20.6	21.2	21.3	21.3	21.2
1966	16.3	16.3	16.3	16.2	16.2	16.2	16.2
1967	20.2	20.7	20.6	20.6	20.6	20.6	20.4
1968	21.3	21.6	21.3	21.3	21.3	21.4	21.5
1969	21.0	20.9	20.8	20.7	20.9	20.9	20.7
1970	18.3	18.4	18.4	18.4	18.4	18.4	18.4
1971	22.0	22.3	22.0	22.0	22.0	22.1	22.2
1972	25.7	25.4	26.1	25.5	25.7	25.5	25.9
1973	25.3	25.4	25.6	25.5	25.5	25.5	25.9
1974	27.0	27.0	27.0	27.0	27.0	27.0	27.0

Source: ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.

Table A18 Simulated Forecasts for Italy
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	9.8	9.6	10.1	9.6	9.8	9.7
1961	12.0	12.3	12.3	11.7	11.6	11.6
1962	13.7	13.4	13.0	13.4	13.4	13.2
1963	12.1	11.7	11.5	11.7	11.8	11.4
1964	12.3	12.0	12.5	12.4	12.4	12.5
1965	13.8	13.8	13.6	14.3	13.6	14.3
1966	13.2	13.6	13.2	13.4	13.2	13.5
1967	13.4	13.2	14.3	13.9	13.6	13.8
1968	14.4	13.7	13.6	13.8	13.9	13.4
1969	13.7	13.7	13.7	13.7	13.7	13.7
1970	14.0	13.8	14.0	13.9	14.0	13.7
1971	14.0	14.1	14.3	14.4	14.0	14.2
1972	13.0	13.4	13.4	13.6	13.4	13.4
1973	12.6	12.3	12.6	12.7	12.7	12.7
1974	13.0	14.3	13.5	13.9	13.9	13.7

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	9.7	9.6	9.7	9.7	9.7	9.7	9.7
1961	11.7	11.9	11.9	11.9	11.9	11.9	11.9
1962	13.2	13.5	13.5	13.6	13.6	13.6	13.6
1963	11.6	11.6	11.6	11.6	11.6	11.6	11.6
1964	12.5	12.5	11.8	12.2	12.3	12.3	12.3
1965	14.2	14.0	14.0	14.0	14.0	14.0	14.0
1966	13.2	13.2	13.6	13.4	13.4	13.4	13.4
1967	13.7	13.8	13.7	13.7	13.7	13.7	13.7
1968	13.7	13.4	13.7	13.8	13.7	13.8	13.9
1969	13.7	13.7	13.7	13.7	13.7	13.7	13.7
1970	13.7	13.7	13.9	13.9	13.9	13.9	13.9
1971	14.2	14.2	14.4	14.2	14.4	14.4	14.3
1972	13.6	13.4	13.6	13.6	13.5	13.4	13.4
1973	12.7	12.7	12.7	12.9	12.9	12.8	12.7
1974	13.7	13.7	13.7	13.7	13.7	13.7	13.7

Source: ECON calculations based on UK Grain Bulletin and FAO Production Yearbook data.

Table A17 Simulated Forecasts for India
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1950	14.6	14.7	14.1	15.0	15.5	14.7
1961	16.5	16.1	15.6	15.4	15.5	15.4
1962	17.0	17.4	16.8	17.7	16.9	16.9
1963	15.2	15.0	15.6	15.7	16.1	15.3
1964	14.4	14.4	13.8	14.3	14.0	13.9
1965	17.6	17.9	18.1	17.6	16.5	17.3
1966	15.5	14.7	15.8	14.6	14.5	14.9
1967	16.2	16.2	16.2	16.2	16.2	16.2
1968	24.1	23.4	24.0	24.1	23.7	23.7
1969	26.2	26.2	27.8	25.4	27.3	26.6
1970	28.2	27.6	28.8	28.6	28.7	28.7
1971	33.7	34.7	35.8	32.9	34.4	34.0
1972	38.4	39.1	38.3	38.4	38.7	38.8
1973	37.7	37.7	36.7	34.7	34.2	36.4
1974	33.8	33.1	33.0	31.3	32.3	33.0

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	14.5	14.3	14.8	14.5	14.8	14.6	14.7
1961	15.5	15.4	15.4	15.6	15.4	15.8	15.7
1962	17.0	17.5	16.9	17.2	17.5	17.6	17.3
1963	15.3	15.5	15.3	15.3	15.3	15.6	15.4
1964	14.0	13.9	14.3	14.2	14.1	14.3	14.2
1965	17.4	17.4	17.3	17.6	17.8	17.7	17.6
1966	14.9	14.5	15.0	14.8	14.9	14.8	14.9
1967	16.2	16.2	16.0	16.1	16.2	16.5	16.3
1968	23.7	23.7	23.7	23.7	23.7	23.6	23.6
1969	26.7	26.7	26.7	26.7	26.7	26.7	26.7
1970	28.7	28.7	28.7	28.7	28.7	28.7	28.7
1971	34.1	33.9	33.8	33.4	33.7	34.0	34.0
1972	37.8	38.1	38.1	37.9	37.9	37.7	37.8
1973	36.0	35.0	34.6	35.4	35.1	35.5	35.6
1974	32.9	33.4	33.4	33.4	33.0	33.3	32.9

Source: ECON calculations based on UK Grain Bulletin and FAO Production Yearbook data.

Table A19 Simulated Forecasts for the Republic of South Africa (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	1.1	1.1	1.1	1.1	1.1	1.1
1961	1.3	1.3	1.3	1.3	1.3	1.4
1962	1.0	1.0	1.0	1.0	1.0	1.0
1963	1.2	1.3	1.4	1.3	1.3	1.3
1964	1.6	1.6	1.5	1.5	1.6	1.6
1965	1.0	1.0	1.0	1.0	1.0	1.0
1966	0.8	0.9	0.8	0.9	0.9	0.8
1967	1.6	1.5	1.6	1.6	1.6	1.6
1968	1.8	1.8	1.8	1.8	1.9	1.9
1969	1.9	1.8	1.9	1.9	1.8	1.8
1970	1.9	2.1	2.1	2.1	2.0	2.0
1971	2.5	2.5	2.4	2.4	2.4	2.4
1972	2.3	2.5	2.4	2.4	2.4	2.5
1973	2.6	2.6	2.6	2.6	2.7	2.5
1974	2.7	2.6	2.5	2.5	2.6	2.6

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	1.1	1.1	1.1	1.1	1.2	1.2	1.1
1961	1.3	1.3	1.2	1.3	1.3	1.3	1.3
1962	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1963	1.3	1.3	1.3	1.3	1.3	1.3	1.3
1964	1.5	1.6	1.6	1.6	1.6	1.6	1.6
1965	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1966	0.9	0.9	0.9	0.9	0.9	0.9	0.9
1967	1.6	1.6	1.6	1.5	1.6	1.6	1.6
1968	1.9	1.9	1.9	1.9	1.9	1.9	1.9
1969	1.9	1.9	1.9	1.8	1.9	1.9	1.9
1970	2.1	2.0	2.0	2.0	2.0	2.0	2.0
1971	2.4	2.4	2.5	2.4	2.4	2.4	2.4
1972	2.5	2.4	2.4	2.4	2.5	2.4	2.4
1973	2.6	2.6	2.6	2.6	2.5	2.6	2.6
1974	2.5	2.4	2.5	2.6	2.5	2.6	2.6

Source: ECON calculations based on UK <u>Grain Bulletin</u> and FAO <u>Production Yearbook</u> data.

Table A20 Simulated Forecasts for Spain
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	5.0	5.1	4.7	5.1	5.1	5.0
1961	4.8	4.7	4.6	4.9	4.7	4.7
1962	7.0	7.2	6.6	6.8	6.4	7.1
1963	7.8	7.6	7.8	8.1	7.4	7.6
1964	7.3	7.0	6.7	6.8	7.2	7.1
1965	5.6	5.7	5.6	5.4	5.9	5.8
1966	6.6	6.6	6.8	6.8	6.9	6.8
1967	6.9	7.3	7.0	7.3	6.8	7.2
1968	7.9	8.3	8.1	8.0	8.2	8.0
1969	6.4	6.4	6.4	6.5	6.4	6.6
1970	5.9	5.9	5.9	5.7	5.7	6.0
1971	7.8	8.2	8.2	8.1	7.9	7.8
1972	6.3	6.7	6.6	6.4	6.6	6.4
1973	5.6	5.9	5.6	5.5	5.6	5.7
1974	6.6	6.2	6.4	6.6	6.4	6.4

	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	5.1	4.9	5.0	5.0	5.0	5.0	5.0
1961	4.9	5.0	4.9	4.8	4.9	4.9	4.9
1962	6.8	6.9	6.9	7.0	6.9	6.9	6.9
1963	7.8	7.8	7.6	7.8	7.6	7.5	7.6
1964	7.0	7.0	6.9	7.0	7.0	7.1	7.0
1965	5.7	5.9	5.9	5.8	5.7	5.7	5.7
1966	6.7	6.7	6.9	6.8	6.7	6.8	6.7
1967	6.9	7.2	6.9	6.8	7.0	7.0	7.0
1968	8.0	8.1	8.2	8.2	8.2	8.2	8.2
1969	6.6	6.6	6.5	6.6	6.5	6.5	6.6
1970	5.8	6.0	5.8	5.7	6.0	5.9	5.9
1971	7.7	7.7	7.7	7.9	7.8	7.9	7.9
1972	6.7	6.4	6.4	6.6	6.6	6.6	6.6
1973	5.6	5.5	5.6	5.6	5.6	5.6	5.6
1974	6.4	6.4	6.4	6.4	6.4	6.4	6.4

Source: ECON calculations based on UK Grain Bulletin and FAO Production Yearbook data.

Table A21 Simulated Forecasts for the United Kingdom (in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT
1960	4.1	4.5	4.2	4.4	4.0	4.2
1961	3.9	3.5	3.7	3.8	3.6	3.8
1962	5.8	5.4	5.9	5.8	5.5	5.8
1963	4.4	4.2	4.2	4.4	4.3	4.3
1964	5.6	5.6	5.4	5.6	5.4	5.6
1965	6.2	5.7	6.1	6.3	6.1	6.1
1966	4.9	5.0	4.8	5.1	5.0	5.0
1967	5.2	5.6	5.5	5.5	5.6	5.6
1968	4.9	5.0	5.2	4.9	5.1	4.9
1969	4.9	5.0	4.6	4.9	5.0	4.8
1970	5.9	6.1	6.2	5.9	5.7	5.9
1971	6.8	6.8	6.8	7.0	6.9	7.0
1972	6.9	6.9	6.9	6.9	6.9	6.9
1973	7.3	6.9	6.9	7.0	7.0	7.0
1974	8.3	8.1	8.6	8.0	8.3	8.2

YEAR	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	4.2	4.3	4.3	4.3	4.3	4.3	4.3
1961	3.8	3.8	3.8	3.7	3.7	3.7	3.7
1962	5.8	5.6	5.8	5.8	5.6	5.8	5.7
1963	4.3	4.3	4.2	4.3	4.2	4.3	4.3
1964	5.3	5.4	5.4	5.4	5.4	5.4	5.4
1965	6.2	5.8	6.0	6.0	6.0	6.0	6.0
1966	5.0	5.0	5.0	5.0	4.9	5.0	5.0
1967	5.6	5.6	5.6	5.6	5.6	5.6	5.6
1968	4.9	4.8	5.1	5.1	5.1	5.1	5.0
1969	4.9	4.9	4.9	4.9	4.9	4.9	4.9
1970	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1971	6.7	6.7	6.9	6.9	6.9	6.9	6.9
1972	6.9	6.9	6.9	6.9	6.9	6.9	6.9
1973	7.1	7.2	7.2	7.2	7.2	7.2	7.2
1974	8.5	8.5	8.3	8.3	8.4	8.3	8.3

Source: ECON calculations based on UK *Grain Bulletin* and FAO *Production Yearbook* data.

Table A22 Simulated Forecasts for the U.S.S.R.
(in millions of metric tons annually)

YEAR	MAY	JUNE	JULY	AUG	SEPT	OCT	
1960	92.7	92.7	92.7	92.7	92.7	92.7	
1961	97.7	93.5	94.2	94.1	97.7	92.8	
1962	100.4	101.6	100.8	100.8	100.8	100.8	
1963	66.9	69.8	69.4	68.5	68.6	73.0	
1964	105.2	104.9	107.6	111.9	106.7	107.7	
1965	85.8	84.9	85.4	83.3	84.5	83.7	
1966	151.6	144.6	141.6	151.3	149.2	145.7	
1967	107.6	108.6	115.1	116.7	139.4	108.2	
1968	134.1	131.6	133.7	131.8	137.9	134.1	
1969	118.1	117.2	110.6	110.9	112.8	113.0	
1970	148.5	135.8	147.8	136.9	139.5	142.8	
1971	144.9	137.3	146.6	140.7	146.6	145.7	
1972	121.7	127.7	121.1	122.8	127.0	119.0	
1973	160.4	154.5	152.9	154.2	154.9	155.9	
1974	125.2	130.0	138.0	134.4	136.3	135.9	
	NOV	DEC	JAN	FEB	MAR	APR	FINAL
1960	92.7	92.7	92.7	91.3	92.7	92.6	91.9
1961	94.1	97.3	97.7	95.7	96.3	95.9	95.1
1962	100.8	100.8	100.6	100.8	100.6	100.8	100.8
1963	70.7	72.0	72.3	71.8	71.6	71.3	71.1
1964	105.2	106.7	108.0	107.8	107.7	105.2	106.4
1965	87.8	84.7	84.2	85.9	84.5	85.7	85.4
1966	147.4	144.1	144.3	144.1	145.1	143.1	143.7
1967	112.7	109.3	111.9	111.5	109.9	111.6	110.7
1968	135.5	133.4	134.4	139.4	133.6	133.5	133.6
1969	116.1	118.1	111.7	113.1	113.7	115.5	114.1
1970	147.5	138.8	145.1	142.6	141.1	144.2	142.6
1971	140.0	143.4	143.3	139.8	137.8	141.2	141.3
1972	122.9	122.9	122.8	121.9	122.3	122.7	123.0
1973	152.5	157.5	155.7	157.7	156.3	156.2	156.9
1974	134.7	134.7	134.9	134.8	136.3	134.7	135.9

Source: ECON calculations based on UK *Grain Bulletin* and FAO *Production Yearbook* data.

Table A23 Summary of Statistical Analysis of Historical Forecast for the United States

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.2014	741.2893	452.6634	0.6106	11.4864	3.3892	8.7866
June	-1.7964	801.9378	489.1986	0.6100	9.7936	3.1295	8.1134
July	-0.1633	656.1651	514.6196	0.7843	1.7024	1.3047	3.3826
August	0.2867	515.7750	464.3813	0.9004	0.5869	0.7661	1.9862
September	0.4627	418.5021	418.6444	1.0003	0.5348	0.7313	1.8959
October	0.2704	454.1387	437.8662	0.9642	0.2740	0.5234	1.3570
November	0.2704	454.1387	437.8662	0.9642	0.2740	0.5234	1.3570
December	0.2141	434.6022	429.6919	0.9887	0.0693	0.2633	0.6827
January	0.2141	434.6022	429.6919	0.9887	0.0693	0.2633	0.6827
February	0.2141	434.6022	429.6919	0.9887	0.0693	0.2633	0.6827
March	0.2141	434.6022	429.6919	0.9887	0.0693	0.2633	0.6827
April	0.2141	434.6022	429.6919	0.9887	0.0693	0.2633	0.6827

Source: ECON

Table A24 Summary of Statistical Analysis of Historical Forecast for Argentina

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.0191	17.4716	-7.4434	-0.4260	6.5378	2.5569	26.8207
June	0.0191	17.4716	-7.4434	-0.4260	6.5378	2.5569	26.8207
July	-0.0381	20.5635	-6.2574	-0.3043	6.6353	2.5759	27.0199
August	-0.0477	24.6479	-9.0453	-0.3670	6.5264	2.5547	26.7973
September	0.0000	20.2878	-8.1728	-0.2089	6.6001	2.5691	26.9482
October	-0.1525	34.9187	-7.9547	-0.2278	6.6423	2.5773	27.0343
November	-0.0858	39.4039	-7.0481	-0.1789	6.6848	2.5855	27.1205
December	-0.4957	42.5012	-1.0020	-0.0236	6.7799	2.6038	27.3129
January	-0.8866	47.5958	37.0195	0.7777	4.5670	2.1371	22.4167
February	-0.6197	58.0615	64.3053	1.1075	1.3032	1.1416	11.9747
March	-0.7055	57.1536	64.3257	1.1255	1.2127	1.1012	11.5511
April	-0.7817	58.9422	65.9071	1.1182	1.1129	1.0549	11.0657

Source: ECON

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Table A25 Summary of Statistical Analysis of Historical Forecast for Australia

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-0.8389	179.4141	64.0422	0.3570	11.2465	3.3536	25.1088
June	-1.0296	171.1254	69.9315	0.4087	10.8066	3.2873	24.6129
July	-0.8008	168.3443	72.7616	0.4322	10.5858	3.2536	24.3601
August	-1.0296	106.8747	50.1982	0.4697	11.1913	3.3453	25.0471
September	-0.8675	99.0413	46.9305	0.4738	11.2943	3.3607	25.1621
October	-0.6292	122.8985	59.5066	0.4842	10.7886	3.2846	24.5923
November	-0.4481	142.2623	87.9593	0.6183	8.8215	2.9701	22.2376
December	-0.3718	147.6909	101.3698	0.6864	7.6529	2.7664	20.7124
January	-0.2002	138.8078	121.9987	0.8789	4.7568	2.1810	16.3296
February	-0.2479	129.1014	126.4975	0.9798	3.4706	1.8630	13.9483
March	-0.2002	137.5400	131.6302	0.9570	3.3146	1.8206	13.6312
April	-0.0191	166.0650	165.5837	0.9971	0.3046	0.5519	4.1324

Source: ECON

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Table A26 Summary of Statistical Analysis of Historical Forecast for Canada

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.1049	207.6582	15.4935	0.0746	30.8006	5.5498	24.8252
June	0.1049	207.6582	15.4935	0.0746	30.8006	5.5498	24.8252
July	0.1049	207.6582	15.4935	0.0746	30.8006	5.5498	24.8252
August	0.2383	206.7803	11.6764	0.0565	30.8388	5.5533	24.8405
September	0.1430	473.0944	414.0173	0.8751	3.0190	1.7375	7.7722
October	-0.0477	460.5524	425.8910	0.9247	0.5942	0.7709	3.4482
November	-0.0477	462.7200	426.9956	0.9228	0.5796	0.7613	3.4054
December	0.0000	461.8475	426.5934	0.9237	0.5795	0.7612	3.4052
January	0.0095	451.2604	423.3352	0.9381	0.3404	0.5835	2.6099
February	0.0381	451.8738	424.6030	0.9396	0.1989	0.4460	1.9950
March	0.0572	455.1320	426.1435	0.9363	0.1971	0.4440	1.9860
April	0.0477	453.9951	425.7209	0.9377	0.1812	0.4257	1.9043

Source: E(.N

Table A27 Summary of Statistical Analysis of Historical Forecast for France

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-2.0687	168.3962	140.6646	0.8353	8.3627	2.8918	14.3220
June	-2.0687	168.3962	140.6646	0.8353	8.3627	2.8918	14.3220
July	-1.4300	141.4744	154.9094	1.0950	4.3534	2.0865	10.3335
August	-1.2298	188.3680	185.2107	0.9832	3.3930	1.8420	9.1226
September	-0.6959	208.6480	210.9110	1.0108	1.0013	1.0006	4.9557
October	-0.6006	254.8763	238.3331	0.9351	0.2578	0.5077	2.5146
November	-0.5529	256.6213	239.2533	0.9323	0.2426	0.4926	2.4395
December	-0.3051	253.0550	237.7769	0.9396	0.2149	0.4636	2.2959
January	-0.2097	236.6958	230.7220	0.9748	0.1012	0.3182	1.5755
February	-0.2288	236.1778	230.5461	0.9762	0.0897	0.2995	1.4834
March	-0.2097	235.7961	230.4152	0.9772	0.0814	0.2853	1.4127
April	-0.2002	233.9038	229.4909	0.9811	0.0811	0.2847	1.4100

Source: ECON

Table A28 Summary of Statistical Analysis of Historical Forecast for India

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-3.7752	634.8051	690.8967	1.0884	24.6697	4.9669	21.5645
June	-3.2985	658.6623	717.4123	1.0892	22.4037	4.7333	20.5503
July	-3.3939	678.8523	730.6564	1.0763	22.0182	4.6924	20.3727
August	-3.0888	630.1509	698.8555	1.1090	22.8923	4.7846	20.7732
September	-0.5339	983.0516	1004.6730	1.0220	3.5293	1.8786	8.1565
October	-0.4290	964.0667	996.1103	1.0332	3.3409	1.8278	7.9358
November	-0.4862	974.5857	1002.6213	1.0288	3.1683	1.7800	7.7280
December	-0.3718	985.2683	1009.0259	1.0241	3.0227	1.7386	7.5484
January	-0.5529	909.4979	976.9264	1.0741	1.7921	1.3387	5.8121
February	-0.5434	962.4308	1005.0833	1.0443	1.7711	1.3308	5.7781
March	-0.5434	962.4308	1005.0833	1.0443	1.7711	1.3308	5.7781
April	-0.5434	962.4308	1005.0833	1.0443	1.7711	1.3308	5.7781

Source: ECON

Table A29 Summary of Statistical Analysis of Historical Forecast for Italy

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.0095	8.5804	3.2923	0.3837	1.5251	1.2350	9.4555
June	0.0095	8.5804	3.2923	0.3837	1.5251	1.2350	9.4555
July	0.0381	7.7624	3.7013	0.4768	1.4865	1.2192	9.3352
August	0.0858	6.6037	5.4667	0.8278	1.2742	1.1288	8.6427
September	0.0381	9.1121	7.2798	0.7989	1.1749	1.0839	8.2992
October	0.0858	7.8306	7.6547	0.9775	1.0467	1.0231	7.8333
November	0.0763	8.7876	8.2137	0.9347	1.0317	1.0157	7.7771
December	0.0858	9.0984	8.4318	0.9267	1.0212	1.0105	7.7372
January	-0.0381	21.5314	20.8307	0.9675	0.0721	0.2685	2.0555
February	0.0000	21.7441	21.0488	0.9680	0.0549	0.2343	1.7943
March	-0.0191	22.9929	21.9395	0.9498	0.0266	0.1631	1.2485
April	0.0095	21.1770	21.1934	0.9965	0.0046	0.0678	0.5190

Source: ECON

Table A30 Summary of Statistical Analysis of Historical Forecast for the Republic of South Africa

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-0.2479	2.2030	2.8683	1.3020	0.1056	0.3249	19.1465
June	-0.2479	2.2030	2.8683	1.3020	0.1056	0.3249	19.1465
July	-0.2479	2.2030	2.8683	1.3020	0.1056	0.3249	19.1465
August	-0.2479	2.2030	2.8683	1.3020	0.1056	0.3249	19.1465
September	-0.2479	2.2030	2.8683	1.3020	0.1056	0.3249	19.1465
October	-0.2479	2.2030	2.8683	1.3020	0.1056	0.3249	19.1465
November	-0.2765	2.5139	3.2282	1.2842	0.0739	0.2719	16.0243
December	-0.1907	3.7981	3.9071	1.0287	0.0837	0.2892	17.0441
January	-0.2097	3.7135	3.8812	1.0452	0.0808	0.2842	16.7504
February	-0.1239	4.7851	4.6624	0.9744	0.0434	0.2083	12.2742
March	-0.1335	5.0904	4.8846	0.9596	0.0323	0.1797	10.5890
April	-0.1335	5.0904	4.8846	0.9596	0.0323	0.1797	10.5890

Source: ECON

Table A31 Summary of Statistical Analysis of Historical Forecast for Spain

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.0763	2.9392	0.5685	0.1934	1.0102	1.0051	15.4137
June	0.0191	3.9044	1.6237	0.4159	0.9667	0.9832	15.0783
July	0.0281	3.9617	1.9467	0.4914	0.9451	0.9722	14.9085
August	0.0000	4.5315	2.1185	0.4675	0.9425	0.9708	14.8880
September	0.0572	9.5701	7.0140	0.7329	0.6232	0.7895	12.1069
October	0.0191	10.9797	7.8197	0.7122	0.5903	0.7683	11.7822
November	0.0000	12.7520	8.2941	0.6504	0.6037	0.7770	11.9155
December	-0.0477	12.9838	10.1141	0.7790	0.4126	0.6424	9.8509
January	-0.0286	12.7929	9.8850	0.7727	0.4311	0.6566	10.0693
February	-0.0191	14.1044	10.6294	0.7536	0.4025	0.6344	9.7290
March	0.0236	14.4043	10.8543	0.7535	0.3895	0.6241	9.5709
April	0.0000	14.7969	11.1979	0.7568	0.3668	0.6056	9.2890

Source: ECON

Table A32 Summary of Statistical Analysis of Historical Forecast for the United Kingdom

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-0.7317	19.6392	12.0854	0.6154	1.0722	1.0355	18.2551
June	-0.8389	25.7739	14.7046	0.5736	0.9919	0.9960	17.5582
July	-0.8580	26.3247	14.7710	0.5611	1.0068	1.0034	17.6889
August	-0.5053	29.0730	15.5140	0.5336	1.0075	1.0037	17.6954
September	-0.1144	17.1717	15.9775	0.9305	0.5007	0.7076	12.4752
October	-0.3051	20.0755	19.1334	0.9531	0.2416	0.4915	8.6648
November	-0.2574	20.8934	19.5561	0.9360	0.2363	0.4861	8.5695
December	-0.2383	21.5941	19.9787	0.9252	0.2225	0.4717	8.3150
January	-0.1621	26.0057	21.9963	0.8458	0.2131	0.4617	8.1392
February	-0.0191	24.9014	22.6916	0.9113	0.0537	0.2317	4.0856
March	0.0095	24.3943	22.5893	0.9260	0.0352	0.1877	3.3094
April	0.0286	23.1837	22.0304	0.9503	0.0340	0.1843	3.2492

Source: ECON

Table A33 Summary of Statistical Analysis of Historical Forecast for the U.S.S.R.

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-6.7973	3911.6401	3822.3148	0.9772	393.6023	19.8394	16.9827
June	-6.7973	3911.6401	3822.3148	0.9772	393.6023	19.8394	16.9827
July	-6.3778	3975.1902	3881.9223	0.9765	389.3090	19.7309	16.8898
August	-5.8725	4446.4251	4026.1395	0.9055	400.4830	20.0121	17.1305
September	-5.8725	4446.4251	4026.1395	0.9055	400.4830	20.0121	17.1305
October	-6.5971	3804.0539	3819.3374	1.0040	385.9367	19.6453	16.8165
November	-5.6247	3803.2195	3729.7872	0.9807	399.5451	19.9886	17.1104
December	-3.3176	5564.8873	4901.0268	0.8807	348.8845	18.6784	15.9889
January	-3.3176	5564.8873	4901.0268	0.8807	348.8845	18.6784	15.9889
February	-3.3176	5564.8873	4901.0268	0.8807	348.8845	18.6784	15.9889
March	-4.0135	6056.9066	5229.3382	0.8634	333.6167	18.2652	15.6351
April	-0.6387	6671.1127	6674.1746	1.0005	167.2786	12.9336	11.0713

Source: ECON

Table A34 Summary of Statistical Analysis of Simulated Forecast for the United States

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.2559	557.9543	478.7839	0.8581	1.1455	1.0703	2.7747
June	-0.1533	415.4751	413.1949	0.9945	1.1393	1.0674	2.7673
July	-0.0130	477.6002	449.7507	0.9417	0.1703	0.4126	1.6596
August	0.0885	420.9611	422.0927	1.0029	0.1854	0.4306	1.1164
September	0.1786	461.5637	442.0857	0.9578	0.1776	0.4214	1.0926
October	0.1121	422.1342	422.7135	1.0014	0.1881	0.4337	1.1243
November	0.0969	452.6800	438.0151	0.9676	0.1472	0.3836	0.9945
December	0.1625	436.1207	430.5967	0.9873	0.0458	0.2141	0.5555
January	0.0540	424.5037	424.0451	1.0008	0.0425	0.2060	0.5342
February	0.1693	430.8423	427.9757	0.9933	0.0470	0.2167	0.5618
March	0.1099	431.6584	428.5030	0.9927	0.0283	0.1697	0.4361
April	0.0416	437.2902	431.1660	0.9860	0.0470	0.2168	0.5621

Source: ECON

Table A35 Summary of Statistical Analysis of Simulated Forecasts for Argentina

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.0660	100.2164	93.4260	0.9307	0.0647	0.2543	2.6680
June	0.0654	85.8145	86.5422	1.0085	0.0682	0.2611	2.7392
July	0.1364	98.1922	92.6283	0.9433	0.0602	0.2454	2.5739
August	0.0203	86.7041	87.2013	1.0057	0.0355	0.1883	1.9755
September	-0.0118	84.9910	85.9871	1.0117	0.0898	0.2997	3.1436
October	0.0318	85.9683	86.8538	1.0103	0.0319	0.1785	1.6721
November	0.1209	97.1748	92.3810	0.9507	0.0261	0.1614	1.6931
December	-0.0760	83.2906	85.4182	1.0255	0.0433	0.2080	2.1815
January	0.0033	92.3245	90.2767	0.9757	0.0211	0.1454	1.5253
February	0.0187	87.1579	87.4736	1.0036	0.0286	0.1692	1.7745
March	-0.0011	90.9351	89.4383	0.9835	0.0154	0.1241	1.3013
April	0.0304	89.8470	88.9366	0.9899	0.0098	0.0989	1.0368

Source: ECON

Table A36 Summary of Statistical Analysis of Simulated Forecasts for Australia

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-0.0597	175.8905	171.6008	0.9756	0.1268	0.3561	2.6661
June	0.2947	176.7368	171.2988	0.9692	0.2350	0.4848	3.6297
July	-0.0372	168.2501	168.2281	0.9999	0.0660	0.2569	1.9235
August	0.0326	165.0493	165.8418	1.0048	0.1866	0.4320	3.2344
September	-0.0179	169.3073	168.6813	0.9963	0.0774	0.2783	2.0834
October	0.1240	159.4651	163.7706	1.0270	0.0671	0.2590	1.9389
November	0.0275	161.2270	164.7431	1.0218	0.0560	0.2367	1.7722
December	0.1124	191.4010	179.6761	0.9387	0.0304	0.1742	1.3045
January	0.1205	170.7043	169.6389	0.9938	0.0372	0.1929	1.4446
February	-0.0886	169.4245	168.9374	0.9971	0.0471	0.2171	1.6251
March	0.0790	169.5320	169.1209	0.9976	0.0273	0.1651	1.2365
April	-0.0043	170.6129	169.4150	0.9965	0.0188	0.1372	1.0276

Source: ECON

Table A37 Summary of Statistical Analysis of Simulated Forecasts for Canada

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-0.0246	387.6262	391.4904	1.0100	0.4747	0.6890	3.0819
June	0.1034	421.1328	408.2906	0.9695	0.4403	0.6635	2.9661
July	0.0272	388.3523	394.1676	1.0150	0.1149	0.3390	1.5162
August	0.1296	430.1239	413.8372	0.9621	0.2613	0.5112	2.2865
September	0.0464	352.9284	375.1251	1.0629	0.2189	0.4679	2.0929
October	0.0879	419.0592	409.6846	0.9776	0.0803	0.2834	1.2679
November	0.0890	405.5257	402.7825	0.9932	0.1158	0.3404	1.5225
December	0.1678	417.0797	408.6294	0.9797	0.0933	0.3055	1.3666
January	0.1242	414.7962	407.7120	0.9829	0.0627	0.2504	1.1200
February	0.0182	421.0013	410.9453	0.9761	0.0334	0.1828	0.8176
March	-0.0867	399.2338	400.1519	1.0023	0.0378	0.1945	0.8708
April	0.0321	406.3856	403.9821	0.9939	0.0100	0.1001	0.4476

Source: ECON

Table A38 Summary of Statistical Analysis of Simulated Forecasts for France

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-0.0768	219.0121	220.2120	1.0055	0.3690	0.6074	3.0083
June	0.1520	200.9241	210.8097	1.0492	0.3872	0.6222	3.0817
July	-0.1093	210.7110	216.2089	1.0261	0.3358	0.57[illegible]	2.8697
August	-0.1038	215.3577	218.1324	1.0129	0.4056	0.[illegible]	3.1539
September	0.0724	248.2931	235.7002	0.9493	0.1899	0.[illegible]	2.1584
October	-0.2860	223.7325	224.2220	1.0022	0.1156	0.3400	1.6837
November	-0.0218	221.5230	223.3603	1.0083	0.0738	0.2754	1.3640
December	-0.0674	229.0885	227.2888	0.9921	0.0547	0.2340	1.1588
January	-0.0444	229.0926	227.3681	0.9925	0.0429	0.2072	1.0264
February	-0.0409	213.0259	221.9213	1.0179	0.0253	0.1590	0.7876
March	-0.0217	221.9139	223.9077	1.0090	0.0227	0.1508	0.7469
April	0.0065	222.5173	224.2188	1.0076	0.0217	0.1472	0.7290

Source: ECON

Table A40 Summary of Statistical Analysis of Simulated Forecasts for Italy

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-0.0622	18.5723	19.0239	1.0243	0.1233	0.3512	2.6889
June	-0.0569	20.9896	20.4271	0.9732	0.0931	0.3051	2.3360
July	-0.0185	17.7548	18.7139	1.0540	0.1050	0.3240	2.4809
August	0.0249	23.3804	22.0680	0.9439	0.0200	0.1415	1.0837
September	-0.0506	19.1686	19.8616	1.0362	0.0392	0.1981	1.5167
October	-0.0623	21.4683	20.9765	0.9771	0.0457	0.2137	1.6363
November	-0.0604	20.6792	20.6874	1.0004	0.0303	0.1741	1.3331
December	-0.0633	20.4006	20.5978	1.0097	0.0225	0.1501	1.1490
January	-0.0245	22.2819	21.5117	0.9654	0.0247	0.1573	1.2045
February	0.0048	20.8232	20.9250	1.0049	0.0048	0.0693	0.5303
March	0.0120	21.0452	21.0407	0.9998	0.0041	0.0642	0.4918
April	0.0133	21.3230	21.1905	0.9938	0.0024	0.0488	0.3735

Source: ECON

Table A39 Summary of Statistical Analysis of Simulated Forecasts for India

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.2389	1129.8308	1102.6712	0.9674	0.4560	0.6753	2.9319
June	0.1787	1170.9054	1117.4715	0.9544	0.4750	0.6892	2.9923
July	0.3265	1172.5483	1119.5197	0.9548	0.2894	0.5379	2.3355
August	-0.2173	1005.1849	1055.5532	1.0302	0.4471	0.6686	2.9030
September	-0.0657	1078.0818	1072.3243	0.9947	0.4656	0.6824	2.9627
October	0.0238	1148.1589	1109.2722	0.9661	0.0730	0.2701	1.1727
November	-0.0566	1104.6925	1088.4423	0.9853	0.0169	0.1300	0.5645
December	-0.0493	1092.1663	1081.7692	0.9905	0.0907	0.3012	1.3078
January	-0.0054	1075.8083	1073.3224	0.9976	0.1453	0.3811	1.6547
February	-0.0551	1080.9477	1076.4066	0.9958	0.0589	0.2428	1.0541
March	-0.0352	1063.0201	1067.5402	1.0043	0.0440	0.2097	0.9103
April	0.0629	1069.0896	1070.6911	1.0015	0.0274	0.1654	0.7133

Source: ECON

Table A41 Summary of Statistical Analysis of Simulated Forecasts for the Republic of South Africa

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.0000	5.2512	5.1531	0.9813	0.0038	0.0620	3.6560
June	0.0088	5.3555	5.2144	0.9740	0.0021	0.0463	2.7276
July	0.0001	4.8876	4.9801	1.0189	0.0025	0.0499	2.9424
August	-0.0032	4.9440	5.0087	1.0131	0.0025	0.0500	2.9493
September	0.0123	5.2139	5.1463	0.9870	0.0021	0.0457	2.6949
October	0.0054	5.0930	5.0864	0.9987	0.0021	0.0455	2.6835
November	0.0093	5.0848	5.0828	0.9996	0.0020	0.0446	2.6295
December	-0.0068	4.8226	4.9446	1.0253	0.0028	0.0534	3.1452
January	-0.0027	5.0697	5.0835	1.0027	0.0007	0.0270	1.5935
February	-0.0084	4.9369	5.0154	1.0159	0.0009	0.0299	1.7607
March	-0.0052	4.9276	5.0133	1.0174	0.0005	0.0222	1.3071
April	0.0049	5.2058	5.1545	0.9901	0.0002	0.0153	0.9039

Source: ECON

Table A42 Summary of Statistical Analysis of Simulated Forecasts for Spain

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	-0.0181	13.3133	13.0858	0.9829	0.0293	0.1711	2.6240
June	0.0525	14.9178	13.8034	0.9233	0.0362	0.1902	2.9174
July	-0.0535	16.5325	14.6325	0.8851	0.0225	0.1498	2.2979
August	0.0150	15.8527	14.2213	0.8971	0.0373	0.1931	2.9619
September	-0.0377	13.3843	13.1110	0.9796	0.0307	0.1753	2.6882
October	0.0248	13.3337	13.1830	0.9887	0.0161	0.1267	1.9434
November	-0.0054	12.0745	12.5684	1.0409	0.0123	0.1110	1.7021
December	0.0299	12.7328	12.8875	1.0121	0.0153	0.1237	1.8963
January	-0.0082	12.9369	13.0380	1.0078	0.0079	0.0889	1.3640
February	0.0043	14.5411	13.8020	0.9492	0.0109	0.1046	1.6039
March	0.0022	13.3463	13.2708	0.9949	0.0024	0.0490	0.7506
April	0.0196	13.2320	13.2149	0.9987	0.0035	0.0587	0.9005

Source: ECON

Table A43 Summary of Statistical Analysis of Simulated Forecasts for the United Kingdom

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	0.0035	21.9797	21.4881	0.9776	0.0284	0.1684	2.9684
June	-0.0559	19.7234	20.3359	1.0311	0.0314	0.1773	3.1255
July	-0.0130	23.4311	22.2157	0.9481	0.0241	0.1551	2.7347
August	0.0294	19.1625	20.1170	1.0498	0.0198	0.1406	2.4783
September	-0.0432	22.0885	21.6127	0.9785	0.0176	0.1327	2.3391
October	-0.0074	20.7590	21.0051	1.0119	0.0094	0.0968	1.7067
November	0.0063	22.2263	21.7169	0.9772	0.0118	0.1085	1.9120
December	-0.0193	21.6373	21.4370	0.9907	0.0106	0.1028	1.8131
January	0.0164	20.9560	21.1517	1.0093	0.0021	0.0454	0.8004
February	0.0100	21.2361	21.2971	1.0029	0.0014	0.0368	0.6495
March	-0.0085	22.2575	21.7900	0.9790	0.0034	0.0580	1.0227
April	0.0054	21.5649	21.4616	0.9952	0.0013	0.0363	0.6406

Source: ECON

Table A44 Summary of Statistical Analysis of Simulated Forecasts for the U.S.S.R.

Month	Forecast Bias (MMT)	RSS_1 $(MMT)^2$	RSS_1 $(MMT)^2$	Slope of Regression	MS Residual Variance $(MMT)^2$	RMS (MMT)	RMS (% of Actual)
May	1.2263	10431.4964	9564.7211	0.9169	6.2993	2.5098	2.1484
June	-0.6569	8549.9955	8643.7145	1.0110	8.7230	2.9535	2.5282
July	-0.0561	8899.9057	8829.2733	0.9921	7.1275	2.6697	2.2853
August	-0.0831	9000.2644	8830.4663	0.9811	14.4606	3.8027	3.2551
September	0.8048	9568.8979	9153.1264	0.9565	7.4184	2.7237	2.3315
October	-0.0989	9149.1159	8969.5534	0.9804	4.4880	2.1185	1.8135
November	0.5561	8869.3368	8822.1731	0.9947	5.8923	2.4274	2.0779
December	0.2599	8639.8689	8723.6046	1.0097	3.3621	1.8336	1.5698
January	0.4882	8814.0441	8817.9295	1.0004	2.3110	1.5202	1.3013
February	0.3966	8927.9191	8869.0845	0.9934	3.1709	1.7807	1.5243
March	-0.1876	8558.4523	8698.9155	1.0152	1.5765	1.2556	1.0742
April	0.1223	8697.7116	8769.6171	1.0083	0.7184	0.8476	0.7255

Source: ECON

APPENDIX B

Empirical Result Data

Table B.1 Human Demand for Wheat in the U.S.

Variables...

VHDBD	Per Capita Human Demand in the U.S.	
VHDBDL 1	Per Capita Human Demand in the U.S.	Lagged One Period
VPMWL2	Constant Dollar Cash Price of Wheat	Lagged Two Periods
VINCPBD	Constant Dollar Per Capita Income	
DUM644 DUM651	Dummy Variables for 4th Quarter 1964 and 1st quarter 1965	
VD1 VD2 VD4	Seasonal Dummies	
c	Constant	

Mean of Dependent Variable is 650.3252

Independent Variable	Estimated Coefficient	Standard Error	T-Statistic	Mean of Variable
VHDBDL1	[illegible]	0.11595613	2.08516121	651.12267031
VPMWL2	[illegible]	[illegible]	-1.90774727	174.15824399
VINCPBD	[illegible]	[illegible]	-4.63723860	0.02657662
DUM644	[illegible]	14.96657944	6.43223953	0.02083333
DUM651	[illegible]	[illegible]	-5.75046730	0.02083333
VD1	[illegible]	[illegible]	2.59000301	0.25000000
VD2	[illegible]	[illegible]	2.94696105	0.25000000
VD4	[illegible]	[illegible]	-0.21845245	0.25000000
C	[illegible]	[illegible]	6.56314096	1.00000000

R-Squared = 0.8614
R-Squared (Adj. For Degrees of Freedom) = 0.8329
F-Statistic (8, 39) = 30.2894
Durbin-Watson Statistic (Adj. For 0 Gaps) = 1.5626
Number of Observations = 48
Sum of Squared Residuals = 7779.05
Standard Error of the Regression = 14.1231

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Table B.2 Demand For Wheat as Annual Feed in the U.S.

Variables...

FDFDNOT	First Difference of Feed Demand Per Annual
FD1FDNOT	First Difference of Feed Demand Per Annual Lagged One Period
FD2PMW	First Difference of What Price in Lagged Two Periods
VD1	
DVD1	
VD2	
DVD2	
VD4	Seasonal Dummies for the periods 3/64-4/67 and 1/68-4/72
DVD4	
C	
DC	

Mean of Dependent Variable is 0.0000

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
FD1FDNOT	-0.50185249	0.17139763	-2.92786410	0.00000009
FD2PMW	-0.00000433	0.00000222	-1.95583153	-1.71567535
VD1	-0.00020762	0.00011131	-1.86522770	0.23529410
DVD1	0.00152876	0.00022351	6.83980465	0.14705678
VD2	-0.00016966	0.00010456	-1.62268257	0.23529410
DVD2	0.00013150	0.00034620	0.37985492	0.14705878
VD4	-0.00046217	0.00010346	-4.46642328	0.26470564
DVD4	0.00069595	0.00016910	3.68034340	0.14705478
C	0.00019411	0.00006419	3.02386665	1.00000000
DC	-0.00056127	0.00018414	-3.04796600	0.58823526

R-Squared = 0.9697
R-Squared (adj. For Degrees of Freedom) = 0.9583
F-Statistic (9, 24) = 85.2627
Durbin-Watson Statistic (Adj. For 0 Gaps) = 1.9480
Number of Observations = 34
Sum of Squared Residuals = 0.387844E-06
Standard Error of the Regression = 0.127123E-03

Table B.3 Seed Demand For Wheat in the U.S.

Variables...

FDSD	First Difference of Seed Demand in the U.S.
FDPMS	First Difference of Spot Wheat Prices
FDFAW	First Difference of Futures Wheat Prices
FDFAS	First Difference of Average Price of Substitutes
FDSDL	First Difference of Seed Demand Lagged One Period

Mean of Dependent Variable is 684.7000

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
FDPMS	204.82279968	91.28611755	2.24374485	7.19999981
FDFAW	117.35762024	91.26560974	1.28569058	-2.69370060
FDFAS	-149.85322571	123.59773254	-1.21242619	-0.81250000
FDSDL	0.29587013	0.27788663	1.06471443	-212.69999390

R-Squared = 0.7374
R-Squared (Adj. For Degrees of Freedom) = 0.6061
F-Statistic (3, 6) = 5.61711
Durbin-Watson Statistic (Adj. For 0 Gaps) = 2.1239
Number of Observations = 10
Sum of Squared Residuals = 0.136586E 09
Standard Error of the Regression = 4771.20

Table B.4 Demand for Commercial Stocks in the U.S.

Variables...

VSC	Level of Commercial Stocks
VFAWPMW	Spread Between Futures and Spot Prices for Wheat
VSCL1	Level of Commercial Stocks Lagged One Period
VD1	
VD2	Seasonal Dummies
VD4	
C	Constant

Mean of Dependent Variable is 273.3904

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
VFAWPMW	0.89790130	1.54784489	0.58009768	-5.48633194
VSCL1	0.89820421	0.06561655	13.68868351	276.70288086
VD1	-43.97752380	17.95742798	-2.44898701	0.24444443
VD2	-57.70379639	17.88693237	-3.22603035	0.24444443
VD4	-25.19372559	18.51463318	-1.36074638	0.26666665
C	61.35444641	19.32029724	3.17564678	1.00000000

R-Squared = 0.8575
R-Squared (Adj. For Degrees of Freedom) = 0.8392
F-Statistic (5, 39) = 46.9303
Durbin-Watson Statistic (Adj. For 0 Gaps) = 2.1225
Number of Observations = 45
Sum of Squared Residuals = 65846.4
Standard Error of the Regression = 41.0898

Table B.5 Area Harvested for Wheat in the U.S.

Variables...

FDAH	First Difference of Area Harvested
VFAW	Level of Wheat Futures Price
VAHL	Level of Area Harvested Lagged One Period
DUM67	Dummy Variable
C	Constant

Mean of Dependent Variable is 688.4165

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
VFAW	25.54772949	5.53797150	4.61319256	183.34915161
VAHL	-0.4[illegible]4601	0.19673377	-2.36434174	20024.50000000
DUM67	3640.33862305	1243.90966797	2.92652893	0.08333331
C	5015.21484375	4102.26171875	1.22254848	1.00000000

R-Squared = 0.8074
R-Squared (Adj. For Degrees of Freedom) = 0.7352
F-Statistic (3, 8) = 11.1817
Durbin-Watson Statistic (Adj. For 0 Gaps) = 2.5654
Number of Observations = 12
Sum of Squared Residuals = 0.112581E 08
Standard Error of the Regression = 1186.28

Table B.6 Rest of World Demand for Wheat

Variables...

ROWTDNS	Per Capita Rest of World Demand for Wheat
LROWTDNS	Per Capita Rest of World Demand for Wheat Lagged One Period
PMWCPL	Deflated Price of Wheat Lagged One Period
PMACPL	Deflated Average Price of Soybeans and Corn Lagged One Period
C	Constant

Mean of Dependent Variable is 3086.4285

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
LROWTDNS	-0.41239303	0.21422613	-1.92503548	3012.90576172
PMWCPL	-683.38378906	184.14628601	-3.71109104	1.67875957
PMACPL	1043.29467773	352.30297852	2.96135616	1.88441849
C	3510.16284180	758.12036133	4.63008595	1.00000000

R-Squared = 0.7090
R-Squared (Adj. For Degrees of Freedom) = 0.5635
F-Statistic (3, 6) = 4.87308
Durbin-Watson Statistic (Adj. For 0 Gaps) = 2.4541
Number of Observations = 10
Sum of Squared Residuals = 158541.
Standard Error of the Regression = 162.553

Table B.7 Rest of World Area Harvested

Variables...

FDROWAH	First Difference of Rest of World Area Harvested
ROWAHL	Level of Rest of World Area Harvested Lagged One Period
FAWFRCPL	Futures Price of Wheat Lagged One Period
C	Constant

Mean of Dependent Variable is 967.7000

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
ROWAHL	-0.34028357	0.18564320	-1.83299732	194342.68750000
FAWFRCPL	3838.92382813	2250.59399414	1.70573711	1.60573864
C	60935.01562500	36478.66406250	1.67042828	1.00000000

R-Squared = 0.4863
R-Squared (Adj. For Degrees of Freedom) = 0.3396
F-Statistic (2, 7) = 3.31389
Durbin-Watson Statistic (Adj. For 0 Gaps) = 1.9918
Number of Observations = 10
Sum of Squared Residuals = 0.129538E 09
Standard Error of the Regression = 4301.79

Table B.8 Wheat Futures Price Adjustment

Variables...

FDFAW	Change in Futures Price
FDLAGFAW	Change in Futures Price Lagged One Period
FDUSHF	Change in U.S. Wheat Forecast
FDROWHF	Change in R.O.W. Wheat Forecast
D643	Dummy Variables for March through June 1964
D644	
D645	
D646	
C	Constant
D1	Seasonal Dummy Variables
D2	
D3	
D4	
D5	
D6	
D7	
D8	
D9	
D10	
D11	
FDSPR	Change in Spread Between Futures and Spot Prices

Mean of Dep ndent variable is -0.2185

Table B.8 Wheat Futures Price Adjustment (continued)

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
FDLAGFAN	0.19740504	0.08492625	2.32442856	-0.20615701
FDUSMF	-0.33331215	0.24241602	-1.37495899	0.06198347
FDRCWHF	-0.08820432	0.06805700	-1.29603577	0.55371898
D643	-14.18966579	5.88566494	-2.41088486	0.00826446
D644	5.45037270	6.01371098	0.90632433	0.00826446
D645	-24.20919800	5.92993069	-4.08254242	0.00826446
D646	-29.88491821	6.23848534	-4.79041195	0.00826446
C	1.43351841	1.80333614	0.79492575	1.00000000
D1	-1.76916218	2.57949734	-0.68585539	0.08264458
D2	-2.21089268	2.53914928	-0.87072176	0.08264458
D3	-1.94532871	2.58497906	-0.75255102	0.08264458
D4	-1.47574902	2.58265305	-0.57140815	0.08264458
D5	-3.88386726	2.64804459	-1.46669197	0.08264458
D6	-1.45761204	2.85196781	-0.51108592	0.09090906
D7	-3.26147842	3.22745514	-1.01054096	0.08264458
D8	1.04570034	2.52834415	0.41367006	0.08264458
D9	2.31624508	2.49739361	0.92746496	0.08264458
D10	1.44571304	2.52989006	0.57145286	0.08264458
D11	-0.83548510	2.51575184	-0.33210152	0.08264458
FDSPR	0.00542806	0.05439793	0.09978426	-0.06523126

R-SQUARED = 0.4777

R-SQUARED (ADJ. FOR DEGREES OF FREEDOM) = 0.3794

F-STATISTIC(19,101) = 4.86163

DURBIN-WATSON STATISTIC (ADJ. FOR 0 GAPS) = 1.8109

NUMBER OF OBSERVATIONS = 121

SUM OF SQUARED RESIDUALS = 3132.10

STANDARD ERROR OF THE REGRESSION = 5.56874

Table B.9 Long Speculation

Variables...

VLS	Level of Long Speculation
SIGMA	World Crop Forecast Error Deviation
VLAGLS	Level of Long Speculation Lagged One Period
C	Constant
A00001	
A00002	Almon Lag Variables on Futures Price of Wheat
A00003	

Mean of Dependent Variable is 43040.7773

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
SIGMA	5259.90234375	1701.32006836	3.09165859	7.14731026
VLAGLS	0.94311857	0.04307560	21.89448547	43040.44921875
C	-36665.48437500	14289.34375000	-2.56593132	1.00000000
A00001	50.94000244	73.81562805	0.69009775	208.88095093
A00002	-85.33654785	61.98852539	-1.37664986	419.43286133
A00003	126.58135986	72.55676270	1.74458313	210.70773315

R-Squared = 0.8251
R-Squared (Adj. For Degrees of Freedom) = 0.8176
F-Statistic (5,116) = 109.469
Durbin-Watson Statistic (Adj. For 0 Gaps) = 1.4631
Number of Observations = 122
Sum of Squared Residuals = 0.801904E 10
Standard Error of the Regression = 8314.42

Table B.9a Long Speculation

DISTRIBUTED LAG INTERPRETATION

	COEFFICIENT	STAD. ERROR	T-STATISTIC	PLOT OF THE LAG DISTRIBUTION(*) AND STAD. ERROR BAND(+)
0	50.94	73.82	0.6901	+ . * +
1	-60.72	35.87	-1.693	+ * + .
2	-85.34	61.99	-1.377	+ * + .
3	-22.90	35.91	-0.6377	+ * . +
4	126.6	72.56	1.745	. + * +

Mean Lag = 24.0907
Standard Error = 21.6556
Sum of Lag Coefficients = 8.56033
Standard Error = 28.5012

Table B.10 Short Hedging

Variables...

VSH	Level of Short Hedging
SIGMA	World Crop Forecast Error Variation
VLAGSH	Level of Short Hedging Lagged One Period
C	Constant
A00001	
A00002	Almon Lag Variables on Futures Price of Wheat
A00003	

Mean of Dependent Variable is 55938.0000

INDEPENDENT VARIABLE	ESTIMATED COEFFICIENT	STANDARD ERROR	T-STATISTIC	MEAN OF VARIABLE
SIGMA	13304.07031250	2818.14868164	4.72085381	7.14731026
VLAGSH	0.85734272	0.05007131	17.12242126	55851.51562500
C	-90086.37500000	22161.01171875	-4.06508350	1.00000000
A00001	-52.36065674	135.75070190	-0.38571185	208.88095093
A00002	-56.82987976	113.58148193	-0.50034457	419.43286133
A00003	179.50952148	131.08242798	1.36943913	210.70773315

R-Squared = 0.7413
R-Squared (Adj. For Degrees of Freedom) = 0.7302
F-Statistic (5,116) = 66.4949
Durbin-Watson Statistic (Adj. For 0 Gaps) = 1.6890
Number of Observations = 122
Sum of Squared Residuals = 0.251295E 11
Standard Error of the Regression = 14718.5

Table B.10a Short Hedging

DISTRIBUTED LAG INTERPRETATION

	COEFFICIENT	STaD. ERROR	T-STATISTIC	PLOT OF THE LAG DISTRIBUTION(*) AND STaD. ERROR BAND(+)
0	-52.36	135.8	-0.3857	+ * . +
1	-84.70	64.08	-1.322	+ * + .
2	-56.83	113.6	-0.5003	+ * . +
3	31.24	65.71	0.4754	+ . * +
4	179.5	131.1	1.369	. + * +

Mean Lag = 36.3789
Standard Error = 19.4753
Sum of Lag Coefficients = 16.8614
Standard Error = 49.7082

APPENDIX C

THE ACCURACY OF LANDSAT CROP AREA MENSURATION AS A FUNCTION OF FIELD SIZE AND SPATIAL RESOLUTION

The mensuration error for crop acreage, isolated from identification error and other sources of error, has been characterized in the NASA's Task Force Report * by the relationship

$$e = \pm 2k\sqrt{\frac{a}{A}} \tag{C.1}$$

where e = relative error of pure mensuration

a = pixel area (approx. 1.1 acres)

A = field size in acres

k = adjustment factor for secondary processing.

While this is a useful first-order analysis of the early results obtained by NASA principal investigators, it is misleading to apply the formula (C.1) to further expected performance results. The implication in the Task Force Report that error can be reduced to zero by increasing the acreage under consideration is false. Further difficulty with the use of (C.1) occurs in relation to statistical significance of results. Actually, (C.1) is a geometrical rather than a statistical relationship. A similar "inverse square root law" of area dependence can be derived from standard statistical theory, which also offers confidence

*D.B.Wood, "The Use of the Earth Resources Technology Satellite (ERTS) For Crop Production Forecasts," Draft final report by Task Force on Agricultural Forecasting, July 1974.

limits for the cited relative error.

C.1 A Statistical Model for Acreage Mensuration Error by LANDSAT

The approach taken here, while rather simplified in terms of the complex phenomena involved in using LANDSAT-MSS to mensurate acreage, is sufficiently detailed to permit a thorough first-order review of the issues raised by the Task Force Report's (TFR) discussion of the theoretical limits of accuracy; and particularly to review use of Equation (C.1) in TFR. There are two important issues at stake:

(i) What is the statistical significance of the formula for relative error?

(ii) What happens in the aggregate, i.e. over a large number of distinct fields of one crop?

In this appendix a new expression for relative error will be derived from the Binomial probability distribution which includes (C.1) as a special case; and a proof will be offered showing that the relative error does not diminish towards zero as the number of fields of one crop in the total acreage increases.

C.1.1 Basic Description of the Binomial Model

The errors in acreage mensuration by use of ERTS-MSS data are almost entirely due to the uncertainty associated with border pixels, as the TFR points out in detail.* The pixels

*Pixel = one picture element, which references approximately 1.1 acres on the ground.

which are "pure" crop, i.e., reflect the interior of a field are assumed to be correctly classified with 100% accuracy after computer processing of the digital tape. Needless to say there may be considerable work involved on recognition algorithms before this result is achieved, but for the time being let us assume it can be done for the major crops of interest and with regard to any field of more than 10 acres. Next consider that "border" pixels (see Fig. C.1) i.e., those which are located along the field boundary and thus do not reflect "pure" crop of one kind, are correctly classified with probability $q_1 = 1 - p_1$. In other words, the error rate of type I: failing to include the pixel area in the field area, is $100p_1$%. The false alarm rate, or type II error is similarly assumed to be a fixed (but possibly unknown) probability p_2. Also $q_2 = 1 - p_2$.

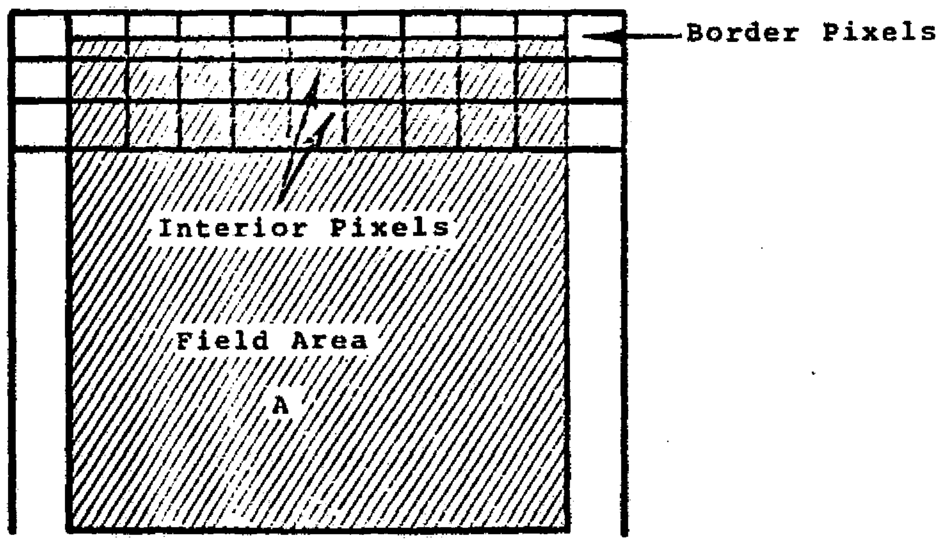

Figure C.1 Pixel Grid Over A Field of Area "A"

C.1.2 Calculation of 95 Percent Confidence Interval for Relative Error

The expected error for a single border pixel is $\alpha(q_1 + p_2) - \alpha$ if that pixel is in fact 100α% crop. The parameter "α" will in general present a problem, particularly since it will vary anywhere from 0 to 1 with unknown distribution. To eliminate it from the model, assume (as does TFR) that the average border pixel is a 50-50 mixture of crop and other content:

$$\alpha = .5 \tag{C.2}$$

For the entire border area, there are

$$N_B = \mu \sqrt{A/a} \tag{C.3}$$

pixels, where μ is a shape factor. For square fields, for instance, $\mu = 4$. If the pixel area is written:

$$a = r^2 \tag{C.4}$$

then the equation (C.1) can be expressed as:

$$N_B = \mu \sqrt{A}/r \quad . \tag{C.5}$$

The number of border pixels classified (correctly or incorrectly) as belonging to field of crop is a random variable with a binomial distribution. Multiplying by the area of a pixel (r^2) leads to the following expression for the total error of acreage mensuration:

$$(\hat{A} - A) = N_B r^2 (0.5(q_1 + p_2) - 0.5)$$
$$= 0.5 N_B r^2 (p_2 - p_1) \tag{C.6}$$
$$= 0.5 \mu r \sqrt{A} \; (p_2 - p_1)$$

where $\hat{A}$ means a statistical estimate of area A based on the binomial probability model. Dividing (C.6) by A to get the relative error:

$$E\left(\frac{\hat{A} - A}{A}\right) = \frac{\mu r}{2\sqrt{A}} (p_2 - p_1) \tag{C.7}$$

The above expression represents an expected value in the statistical sense derived from the binomial model.

In the case of square fields the expression (C.7) can now be compared with the TFR error formula $e = \frac{2kr}{\sqrt{A}}$ since (C.7) yields $e = \frac{2r}{\sqrt{A}} (p_2 - p_1)$. However, even in the event that $k = p_2 - p_1$ (leading to numerical equivalence), the meaning and interpretation of the two formulae differ substantially.

Using this same model, it is possible to obtain an approximate 95% confidence interval for the relative error of mensuration $\left(\frac{\hat{A} - A}{A}\right)$:

$$\text{Prob}\left[ER-(1.96)\sqrt{VR} \le \left(\frac{\hat{A} - A}{A}\right) \le ER + (1.96)\sqrt{VR}\right] = .95$$

where

$$ER = \frac{\mu r}{2\sqrt{A}} \; (p_2 - p_1)$$
$$VR = \frac{\mu r^3}{A^{3/2}} \; (p_2 q_2 + p_1 q_1) \tag{C.8}$$

As an example, consider a square field ($\mu = 4$) of 256 acres and assume a pixel area of 1.1 acres. Then with type I (failure-to-recognize) and type II (false alarm) error rate of 5% and 10%

respectively, the 95% confidence interval for relative error of mensuration is: (.0069 ± .0260) = (-.019, +.033); in other words, from a 1.9% <u>under</u>estimate to a 3.3% <u>over</u>estimate. It is important to recognize

(i) that the expected relative error (0.0069) is small compared with the 2-sigma limits (±0.026) in this example, and

(ii) that the statistical model does not, so far, allow fully for improvements that are possible with sub-pixel processing.

If, for example, the latter uses 10(k = 0.1) grey levels, it may be possible to reduce the relative error to (.0007±.0026), although this is, in a sense, double counting, because the statistical model already allows partially for the removal of uncertainty in recognition of border pixels.

C.1.3 The Statistics of Relative Error for Many Fields

When the analysis used in this section is applied to a large number (M) of fields with areas $A_1, A_2, \ldots, A_M$ will the law of large numbers apply to cause a reduction of relative error of acreage mensuration towards zero? The answer depends on the geometric relationship of the fields. If two fields of crop "A" share a common border, for remote sensing purposes they are one field with enlarged area. The definition of "field" in this context <u>must</u> exclude differences of ownership and other differences not observable by spectral decomposition of reflected

radiance. Thus Figure C.2 does not represent the type of situation at hand. Rather, it is the case for mensuration purposes that fields of one crop are (mostly) unconnected as in Figure C.3. Fields of other crops, or other kinds of land use (such as B in Figure C.3) will be contiguous with the crop "A" fields; the border pixel problem acquires its precise definition in relation to the specific land use patterns of adjoining fields.

Assuming a known distribution of field size represented by a distribution function F, the expected relative error for total acreage is:

$$E\left[\frac{\hat{A}\text{ total} - A\text{ total}}{A\text{ total}}\right] = \frac{0.5\mu r(p_2 - p_1)}{\sqrt{\bar{A}}}$$

where

$$\bar{A} = \left(\frac{\int A\,dF(A)}{\int\sqrt{A}\,dF(A)}\right)^2 \qquad (C.9)$$

For example, if 50% of the fields are of area A acres and the other 50% are of area 2A acres, then expected relative error would be $\frac{0.377\mu r(p_2 - p_1)}{\sqrt{\bar{A}}}$,

which is intermediate between the single-field error for areas A and 2A.

Consider M unconnected fields of identical area, A acres each. In this case

$$\bar{A} = \left(\frac{\frac{1}{M}\sum_{i=1}^{M}(A)}{\frac{1}{M}\sum_{i=1}^{M}(\sqrt{A})}\right)^2 = \left(\frac{A}{\sqrt{A}}\right)^2 = A \qquad (C.10)$$

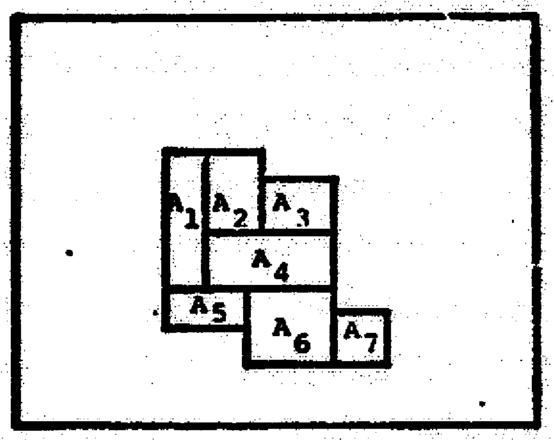

Figure C.2 Many Fields in the Contiguous Case

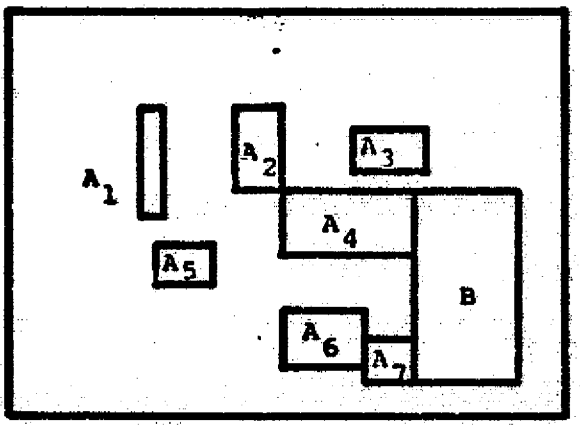

Figure C.3 Many Fields in the Unconnected Case

so that the RE given by (C.9) is <u>the same as</u> (C.7). Thus, in general, no improvement of accuracy can be expected by virtue of a large <u>total</u> acreage if the individual field size is not increased.

The effect of comparing M fields of total area A_{total} with a single field is to reduce the 2-sigma limits for relative error used in (C.8) to derive the 95% confidence interval by a factor of $\sqrt{M}$, while leaving the expected value unchanged. If the expected value is not zero i.e. $p_1 \neq p_2$, then the estimator $\hat{A}_{total}$ can be said to be <u>consistent</u> ($\sigma_M \rightarrow 0$ as $M \rightarrow \infty$) but <u>biased</u> ($E(\hat{A}) \neq A$) in the jargon of modern statistical theory. Furthermore, it is also not <u>asymptotically unbiased</u> since the expected value of $\hat{A}_{total}$ does not even approach A_{total} as M increases without bound. Practically this will not be important in cases such as the example cited above in which the bias is fairly small. For small fields it <u>will</u> present a problem and it is important to stress here that the problem cannot be made to go away by assuming a large number of small fields to be available for mensuration of total crop acreage.

C.1.4 <u>A Sensitivity Analysis of Relative Error for Small Fields</u>

The expected relative error of area mensuration as estimated by (C.7) is open to another interpretation. If the number of pixels in a typical field is $N_p = A/a$, (C.7) can be written:

$$E\left(\frac{\hat{A} - A}{A}\right) = \frac{2(p_2 - p_1)}{N_p} = \frac{2\Delta E}{N_p} \qquad (C.11)$$

for square fields, where: p_2 = "false alarm" rate of error

p_1 = "failure-to-recognize" rate of error.

The difference $\Delta E = (p_2 - p_1)$ between the two error rates is the resultant of several opposing forces. It is not possible at the level of detail of this discussion to decompose this parameter further into its contributory sources, but it should be remarked that, a priori, one might expect ΔE to be substantially different from zero in many agricultural applications. This is because some of the typical field borders will include land cover such as roads and streams which are substantially easier to recognize than the crops under investigation. Furthermore, ΔE will generally be unrelated to the field size, A and the number of fields in the total acreage. As pointed out in the preceeding paragraphs, N_p is not a sample size in the usual sense: it represents sampling within one field only, rather than sampling within the whole crop acreage. Thus, to reduce relative error of mensuration by increasing N_p would imply reduction of the pixel area, a, which can only be achieved by improved spatial resolution of the MSS. Field area, A, is not a system parameter subject to design specification since the system for ERS crop survey must take the fields as they are. Table C.1 contains a sensitivity analysis of relative error for "small" fields in the range 10

to 100 acres with an assumed pixel area of one acre. It is immediately clear from a glance at Table C.1 that the relative error <u>is</u> sensitive to the <u>difference</u> between the two error rates, as well as to the size of the field. But even when the error rates of non-recognition (p_1) and false alarm (p_2) are equal, the actual relative error for a particular small field may be quite large as Table C.2 reveals through sensitivity analysis of the 95% confidence limits for relative error.

Table C.1 Sensitivity Analysis of Relative Error for Small Fields

N_p No. of Pixels per Field	ΔE = Difference Between p_2 and p_1				
	1%	5%	10%	25%	50%
	Percent Relative Error of Area Mensuration				
10	0.6	3.2	6.3	15.8	31.2
20	0.4	2.2	4.5	11.2	22.4
50	0.3	1.4	2.8	7.1	14.1
100	0.2	1.0	2.0	5.0	10.0

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Table C.2 Sensitivity Analysis of Relative Error of Area Mensuration for 100-pixel Scenes with Varying Non-Recognition and False Alarm Error Rates

P_1 = Probability of Non-recognition; P_2 = False Alarm Rate

Parenthetical Figures Are 95% Confidence Limits; Beneath Them Are Expected Values of Relative Error %

P_1 \ P_2	0.00	0.01	0.05	0.10	0.25	0.50
0.00	(0,0) 0	(-1.0, 1.4) 0.2	(-1.7, 3.7) 1.0	(-1.7, 5.7) 2.0	(-0.4, 10.4) 5.0	(3.8, 16.2) 10.0
0.01	(-1.4, 1.0) -0.2	(-1.7, 1.7) 0	(-2.2, 3.8) 0.8	(-2.1, 5.7) 1.8	(-0.7, 10.3) 4.8	(3.5, 16.1) 9.8
0.05	(-3.7, 1.7) -1.0	(-3.9, 2.2) -0.8	(-3.8, 3.8) 0	(-3.6, 5.6) 1.0	(-2.0, 10.0) 4.0	(-2.2, 15.8) 9.0
0.10	(-5.7, 2.1) -2.0	(-5.7, 2.1) -1.8	(-5.6, 3.6) -1.0	(-5.3, 5.3) 0	(-3.5, 9.5) 3.0	(0.9, 15.2) 8.0
0.25	(-10.4, 0.4) -5.0	(-10.3, 0.7) -4.8	(-10.0, 2.0) -4.0	(-9.5, 3.5) -3.0	(-7.6, 7.6) 0	(-3.2, 13.2) 5.0
0.50	(-16.2, -3.8) -10.0	(-16.1,-3.5) -9.8	(-15.8, -2.2) -9.0	(15.2, -0.8) -8.0	(13.2, 3.2) -5.0	(-8.8, 8.8) 0